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RIFT S-N STAGE INTERNAL SYSTEMS PRELIMINARY CONCEPTUAL DESIGN REPORT

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PREPARED UNDER CONTRACT NO. NAS 8-5600

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RIFT S-N STAGE INTERNAL SYSTEMS PRELIMINARY CONCEPTUAL DESIGN REPORT

PREPARED UNDER CONTRACT NO. NAS 8-5600

Approved
A. J. Steele
Director of Engineering

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ERRATA

The following errors in this publication should be corrected as indicated:

Page	Line(s)	Change
1-33	5	"(N∼.001 in.)" to "(∼.001 in.)"
1-36	5	"lightweight" to "resistive"
1-40	7	"sizes larger" to "sizes numerically larger"
1-40	8	"those smaller" to "those numerically smaller"
1-51	5	"rods" to "racks"
2-3	(Table 2-3)	The use of high-speed commutators on the SS/FM link (Ch. 1-5) will cause demultiplexing problems due to the low cutoff of the SS/FM channels (50 cps). This problem can be solved by DC restoration at the ground station or by the addition of another PAM-FM-FM link.
2-7	last	"(0-42 kc)" to "(0.05-1.2 kc)"
2-19	3	"AMR" to "Cape Canaveral"
2-29	next to last	"increase the noise level" to "decrease the gain"
2-31	8	"that at RIFT startup the gamma-" to "that the gamma-"
3-5	15	"60 percent min of" to "60 percent min at"
3-6	16	"Voltage reduction" to "Voltage regulation"

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FOREWORD

This report on the RIFT S-N Stage internal systems preliminary conceptual design is submitted to NASA-MSFC in accordance with discussions held at Marshall Space Flight Center on August 20 to 22, 1962, between contractor personnel and Nuclear Vehicle Project Office personnel.

This document contains three major sections which satisfy the requirement for the submittal on 30 Sept 1962 of design concepts for RIFT S-N Stage electrical systems and instrumentation systems. It is believed that the design concepts associated with the three resultant areas (electrical systems, instrumentation systems and communication systems) are sufficiently interrelated as to warrant inclusion in one document.

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INTRODUCTION

The current status of the design and analysis of the internal systems for the RIFT S-N Stage is presented herein. It is based on the mission and performance requirements currently established for this vehicle. The basic criteria for the designs are derived from the primary objective of the RIFT program to evaluate the characteristics of and the problems associated with operating a nuclear rocket propulsion system in a space environment. Wherever this objective is not compromised, the requirements for an operational nuclear third stage are satisfied as well.

The design concepts presented in this document are intended to be conservative in nature. In addition, efforts have been directed toward the selection of equipment units having proven histories of reliable performance.

The selected configurations provide for maximum system flexibility from the standpoint of both changing requirements and future expansion and provide for an easy transition from the RIFT vehicle system to an operational C-5 nuclear vehicle system.

The principal design features of the RIFT S-N Stage internal systems include the selection of established and proven telemetry techniques developed within current IRIG standards. Alternate approaches will be presented for review by MSFC personnel at a later date.

Particular attention has been directed to the problem of electromagnetic interference. This problem is characteristic of vehicles posessing a multiplicity of systems and could be aggravated by the nuclear radiation environment characteristic of the RIFT vehicle.

Another design feature is that of on-board data recording. The possibility exists that a partial communications blackout could occur during engine run. In order to ensure a complete data profile, serious consideration is therefore being given to such a storage system.

It is hoped that this document will serve as the basis for further technical discussions between MSFC and NSPD in order to ensure compatability of thought in reaching the common goal.

Section 1

MEASURING SYSTEMS DESIGN

The RIFT Stage instrumentation is based upon the Vehicle Measurement List, Table 1-1 (presented at the end of Section 1). Each measurement has been given its own designation and this designation system is explained in the table preceding the Vehicle Measurement List. Each measurement is depicted in Fig. 1-1.

The total number of measurements currently specified is 1,029. The Vehicle Measurement List defines the type of measurement, range, frequency response, accuracy, and other pertinent data.

A condensed transducer list is presented in Table 1-2.

1.1 DATA REQUIREMENTS

This section discusses the RIFT measurement requirements (refer to Table 1-1) and the transducers selected to make these measurements.

The transducers listed in the Vehicle Measurement List are tentative selections based upon information currently available. All transducers and their associated amplifiers will be chosen only after extensive evaluation tests are completed. In general, the considerations for transducer selection to fill these requirements are based on the following ground rules:

- Low output impedance
- High output signal (5 v DC if possible)

- Variable range
- Minimum organic content
- Radiation compensation capability
- Capability to withstand severe environments (including vibration, shock, cryogenic and high temperatures, humidity, and altitude)
- Simplicity
- Low cost

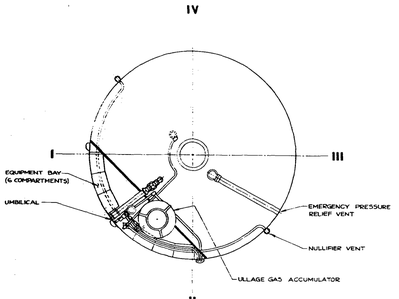
The transducers are, in general, flight-qualified items but the majority have not been qualified for the radiation or cryogenic environments. All pressure transducers will be of the psia variety and will be capable of withstanding at least a 100-percent overpressure. Also, all pressure transducers will have cases capable of at least 300 percent of full-scale pressure; this capability will prevent complete loss or leaks of volatile, corrosive, or highly critical media from damaging components or crippling the vehicle.

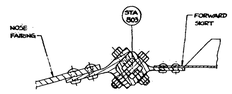
1.1.1 Main Propulsion System

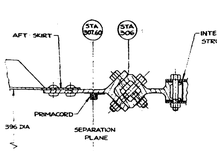
The main propulsion system has a total of 263 measurements specified. Tables 1-3 and 1-4 give a further breakdown of these measurements as to particular parameters and quantities. Figure 1-1 and the Vehicle Measurement List (Table 1-1) present more detailed information.

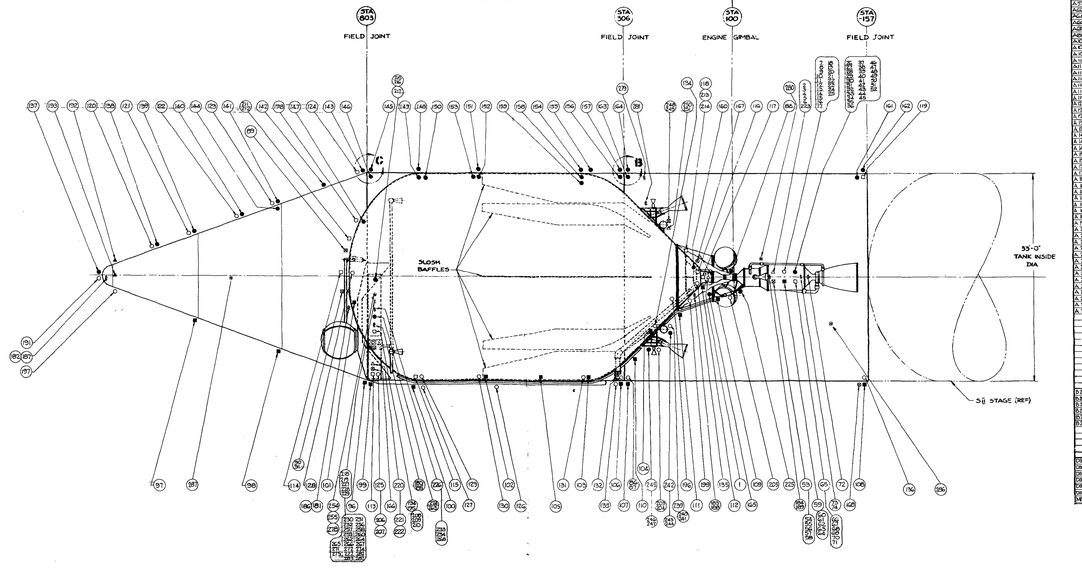
Measuring devices to be used for the main propulsion system are as follows:

(1) Pressure and Position. Potentiometer-type pressure and position transducers have been specified consistent with required accuracy and frequency responses.









| MEASUREMENT TYPES | | |

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Table 1-2

CONDENSED TRANSDUCER LIST FOR RIFT STAGE

Transducer Type	Quantity
Potentiometer	133
Thermocouple	172
Platinum Resistance Thermometer	115
Bonded Strain Gage	186
Unbonded Strain Gage	64
Piezoelectric Type	11
Flowmeters	14
Neutron and Gamma Radiation Detectors	40
H_2 Gas Detectors	4
RPM	1

Table 1-3

CONDENSED MEASURING PROGRAM FOR RIFT STAGE (PART I)

System	Parameter								
	Posit.	Press.	Temp.	Flow Rate	Strain	Vibrat.	Accel.	Rate/rpm	Sequence
Main Propulsion	18	43	118	7	52	7	15	1	2
Secondary Propulsion	-	4	2	3	-	-	-	-	-
Engine Control	15	3	6	-	-	-	-	1	24
Structures	-	54	126	-	134	-	21	-	-
General	-	-	-	-	-	-	-	-	-
General Performance and Control Evaluation	-	15	-	-	-	-	2	-	-
Guidance and Control	5	12	32	-	-	-	8	-	8
Attitude Control	12	6	14	4	-	-	-	-	-
Communications	-	-	-	-	-	-	-	-	-
Ground Space Command	-	-	-	-	-	-	-	-	-
Destruct	-	-	1	-	-	-	-	-	-
Tracking, C-Band Beacon	-	-	-	-	-	-	-	-	-
Azusa	-	-	-	-	-	-	-	-	-
Electrical	-	-	-	-	-	-	-	-	-
S-IC and S-II Stages	16	8	-	-	20	-	8	-	2

Table 1-4

CONDENSED MEASURING PROGRAM FOR RIFT STAGE (PART II)

System	Parameter								
	Voltage, Current, Power	Acoustics	Radiation	Rate (Deg/Sec)	Liquid Level	Thrust	H_2 Leak Det.	Misc.	Total
Main Propulsion	-	-	-	-	-	-	-	-	263
Secondary Propulsion	-	-	-	-	-	-	-	-	9
Engine Control	45	-	-	-	-	-	-	-	94
Structures	-	3	-	-	-	-	-	-	333
General	-	-	40	-	-	-	4	-	44
General Performance and Control Evaluation	-	-	-	-	4	-	-	-	21
Guidance and Control	22	-	-	-	-	-	-	-	87
Attitude Control	-	-	-	-	-	-	-	-	36
Communications	20	-	-	-	-	-	-	-	20
Ground Space Command	5	-	-	-	-	-	-	-	5
Destruct	7	-	-	-	-	-	-	-	17
Tracking, C-Band Beacon	2	-	-	-	-	-	-	-	2
Azusa	2	-	-	-	-	-	-	-	2
Electrical	9	-	-	-	-	-	-	-	9
S-IC & S-II Stages	10	-	-	4	-	10	4	-	82
Total									1029

(2) Temperature. Three types of temperature devices are being considered: Chromel-Constantan thermocouples for intermediate temperatures, Tungsten-Tungsten 26-percent Rhenium for high temperatures (5,000°F), and platinum resistance thermometers for cryogenic temperatures (-423°F).

(3) Flow Rate. The flow-rate measurements are scheduled to be made with mass-type meters. However, a development program on this type of instrument is scheduled as outlined in Subsection 1.2.4.

(4) Stress. Bonded-type strain gages are to be used for stress measurements. (See Subsection 1.3 for typical strain gages currently being considered.) A cryogenic development program will be conducted in this area.

(5) Vibration and Acceleration. Piezoelectric-type vibration pickups are to be used for the high-frequency (2,000-cps) vibration measurements. Gas-damped, unbonded strain gages are scheduled for the lower-frequency (250-cps) acceleration measurements.

(6) Rate/rpm. A magnetic pickup with an associated frequency converter will be used. This simple device, with proper signal conditioning, will provide an unattached method of determining rpm.

(7) Sequence. Sequence measurements will be made with a switch arrangement.

1.1.2 Secondary Propulsion System

The secondary propulsion system has a total of nine measurements specified.

This quantity is further increased by many measurements included under the heading of "guidance and control". Tables 1-1, 1-3, and 1-4, and Fig. 1-1 give more detailed information.

Measuring devices to be used for the secondary propulsion system are as follows:

(1) Pressure. Potentiometer types and unbonded strain-gage types are specified for low and high frequencies, respectively.

(2) Temperature. Platinum resistance thermometers are specified for the temperature measurements.

(3) Flow Rate. Mass-type flowmeters are scheduled for the flow-rate measurements.

1.1.3 Engine Control System

The engine control system has a total of 94 measurements specified. Tables 1-1, 1-3, and 1-4 and Fig. 1-1 give more detailed information. All of the engine control systems measurements will be presented by the engine manufacturer in the form of voltages which will be fed directly to the telemeter after proper signal conditioning.

1.1.4 Structures

A total of 333 measurements have been established to define structure and aerodynamics design. Tables 1-1, 1-3, and 1-4 and Fig. 1-1 give more detailed information.

Measuring devices to be used for structures are as follows:

(1) Stress. The majority of the structural measurements are stress

(134). Bonded-type strain gages are to be used in this measurement.

(2) Vibration and Acceleration. The high- and low-frequency vibrations will be measured by piezoelectric and gas-damped unbonded strain gages, respectively.

(3) Pressure. The pressure measurements to be made are such that potentiometer types will suffice. However, if higher-frequency measurements are required, unbonded strain-gage types will be used.

(4) Temperature. The cryogenic temperature measurements will be made with platinum resistance thermometers because of their greater outputs and accuracies in this range. The intermediate temperatures (0 to 500°F) will be accomplished using Chromel-Constantan thermocouples because of their superior sensitivity.

(5) Acoustic. The acoustic phenomena will be measured with piezoelectric-type high-intensity microphones (120 to 190 db). One particular type incorporates a vibration compensating system as part of the transducer. The unit is light in weight and small in size, and has good frequency response and high sensitivity. Similar units have been used successfully on the Agena vehicle. An associated amplifier boosts the pickup level to 5 v for telemetry purposes.

1.1.5 Guidance and Control System

A total of 87 measurements are scheduled for the guidance and control system. Tables 1-1, 1-3, and 1-4 and Fig. 1-1 give more detailed information.

Measuring devices to be used for the guidance and control system are as follows:

(1) Pressure. Potentiometer-type pressure transducers are scheduled for the lower-frequency measurements and unbonded strain gages for the higher frequencies. All of these transducers will have a case integrity proof pressure of at least 300 percent of the transducer full-scale range; this will improve the guidance and control package reliability.

(2) Vibration and Acceleration. The high- and low-frequency vibration measurements will be made by piezoelectric and gas-damped unbonded strain gages, respectively.

(3) Temperature. The intermediate-range temperature measurements will be made with Chromel-Constantan thermocouples.

1.1.6 Attitude Control

A total of 36 measurements are scheduled for the attitude control system. Tables 1-1, 1-3, and 1-4 and Fig. 1-1 give more detailed information.

Measuring devices to be used for the attitude control system are as follows:

(1) Pressure. Potentiometer-type pressure transducers will be used for the lower-frequency measurements and unbonded strain gages for the higher frequencies. Transducer case integrity to 300 percent full scale will be maintained.

(2) Temperature. Temperature measurements will be made with Chromel-Constantan, since they lie in the intermediate range.

(3) Flow Rate. Flow rates will be measured with either mass- or volumetric-type flowmeters.

1.1.7 Electrical System

A total of nine voltage measurements are required for the electrical system. These voltages will be conditioned and fed directly to the telemeter. Tables 1-1, 1-3, and 1-4 and Fig. 1-1 give more detailed information.

1.1.8 Communications System

A total of 20 voltages are required for the monitoring of the communications system. These voltages will be conditioned and fed to the telemetry package.

1.1.9 Destruct System

Seventeen measurements are required for monitoring of the destruct system. Sixteen of these are voltages and one is a temperature. The voltages will be conditioned and fed directly to the telemetry package.

1.2 TRANSDUCER DEVELOPMENT

As previously mentioned in Subsection 1.1, "Data Requirements," an extensive transducer-development program is scheduled for the RIFT Program. Many measurements will be such that standard-type transducers will satisfy performance and environmental requirements. However, in many cases—to meet the difficult RIFT

performance and environmental requirements – special transducers will have to be developed. Among those transducers under consideration for development are the following: Liquid-level and slosh, high-accuracy temperature, mass flow, airborne type radiation detectors, and strain gages and bonding cements. Each of these transducer developments will be treated individually.

1.2.1 Liquid Level and Slosh

Three basic types of systems are under consideration as offering prospective solutions to worthwhile level and slosh measurements. These three types are:

- Continuous sonic
- Continuous capacitive
- Point sensors

These three types will be discussed in more detail.

1.2.1.1 Sonic – Continuous Readout

A continuous type of sonic liquid-level system was used on the Lockheed Agena vehicle with fair results. In this system, a measuring crystal is used to excite the liquid medium with acoustical energy producing an ultrasonic wave which travels to the liquid-gas interface at the tank top. The difference in density between the gas and liquid creates the interface which reflects a portion of the acoustical energy back to the transducer. If the velocity of sound in the media is known, then the distance can be found. A calibrate crystal is incorporated to determine the velocity of sound in the liquid. Under proper

conditions, this system can produce accurate and usable data. One disadvantage of this system is that stillwells are required for successful operation. The stillwells take up vital propellant space and create tank design problems. Further, no knowledge of the success of this system in LH_2 is available.

A development program is a requirement before this system could be specified, especially with a combined cryogenic-radiation environment.

1.2.1.2 Capacitive – Continuous

The capacitive type of liquid-level system operates on the change in impedance of a capacitance sensor as the dielectric is changed from a gas to a liquid. This capacitance is sensed in a bridge circuit. Any unbalance in the bridge is applied to the input of an amplifier. This system, in order to be continuous, requires a tube of considerable length in the tank. The system could be used for slosh measurement by increasing the number of sensors to two or more.

Similar systems are reported being considered for the Douglas S-IV Saturn Stage. However, a development program is required before this system could be incorporated for use in a cryogenic and radiation environment.

1.2.1.3 Point Sensor

Point sensors of the capacitive, acoustic, magnetostrictive, and optical types have been successfully used in cryogenic media. The acoustic and capacitive units often require some type of stillwell for successful operation. They are also somewhat sensitive to vapor or film residues.

An optical sensor developed by Bendix appears to have definite potential for liquid point sensing. The system functions as follows. Light rays from a self-contained source are directed down one side of a transparent probe material. If no liquid is present at the prism end of the probe, the light is reflected from the prism's two angled surfaces back up the other side to a light sensor. If the prism end is immersed in liquid, the refractive quality of the prism is changed so that the light rays are passed into the liquid without reflection. The sensor output, energizing a relay, creates a simple on-off device. This unit should be evaluated in a radiation-cryogenic environment to determine RIFT vehicle potential.

1.2.2 Strain Gages and Bonding Cements

A good deal of strain-gage and strain-gage-bonding-cement development is anticipated for the RIFT program because of the combined cryogenic-radiation environments.

Subsection 1.3, "Transducer Evaluation Program," lists some information on strain-gage testing, including performance in a radiation environment. However, the combined effects of cryogenic and radiation environments will require a vigorous development program to produce dependable gages and cements. Development of strain gages and cements is constantly taking place at LMSC and the particular problems encountered within the RIFT Program could be handled by the strain-gage research group at the Van Nuys, Calif., facility. Weldable, epoxy-backed, phenolic-backed, and ceramic-backed gages are under consideration. Epoxy, phenolic, and ceramic cements will also be tested.

1.2.3 Temperature Probes

A wide variety of temperature sensors are under consideration for the RIFT Program. They can be classified as follows:

Temperature Range	Type Sensor
-423°F to 0°F	Platinum Resistance Piezoelectric Germanium Carbon
0°F to 2,000°F	Nickel and Tungsten Resistance Chromel-Constantan Thermocouple
2,000°F to 5,000°F	Tungsten-Tungsten 26% Rhenium Thermocouples

1.2.3.1 Low Temperature Range

Platinum resistance thermometers, germanium sensors, and carbon sensors currently are considered the most accurate and reliable for the low-temperature range.

The piezoelectric approach offers an additional highly accurate instrument. The resonant frequency of the crystal changes linearly with temperature through the LH_2 range. This change in resonant frequency can be accurately measured and used as an indication of temperature.

All of these types are under consideration and a development program for use in the combined cryogenic-radiation environment is programmed. Thermocouples have been excluded from consideration in this range because of their extremely low output (gold-cobalt, approximately 12 $\mu v/^{\circ}K$ from 10° to 20°K).

1.2.3.2 Intermediate Temperature Range

Because of their high sensitivity, Chromel-Constantan thermocouples are very suitable for the intermediate temperature range. (Nickel and tungsten type resistance sensors also will function well in this temperature range and provide an alternate method of measurement. The nickel and tungsten sensitivities in this range are greater than that of platinum.) Evaluation tests to determine their susceptibility to radiation will have to be conducted.

1.2.3.3 High Temperature Range

Tungsten-tungsten 26% Rhenium thermocouples will be used for temperatures to 5,000°F. These couples are suitable for use in a vacuum, in hydrogen, and in inert gases such as nitrogen, argon, and helium. This type is especially recommended for use in the range from 3,632°F to 5,072°F. However, its high output also makes it useful for the measurement of temperatures below this range. The high melting point of the elements comprising the thermocouple (tungsten, 3,380°C; Rhenium, 3,167°C) plus a low vapor pressure make it attractive for use in a vacuum at intermediate and high temperature. It should be pointed out that this thermocouple is not suitable for use under oxidizing conditions or in the presence of hydrocarbon vapors which will rapidly attack tungsten at temperatures above 1,832°F.

A vacuum condition should exist for the S-N Stage. Typical values of EMF vs. temperature are listed below (32°F reference):

Temperature (°F)	EMF (mv)
212	0.333
932	4.380
1,832	13.130
2,732	25.130
3,632	34.130
4,532	40.250
5,072	43.250

1.2.4 Flow Rate

Considerable development is anticipated in the area of mass-type flow measurements for the combined environments of cryogenic temperatures and radiation effects. A survey conducted for the RIFT Program indicates that the flowmeter using a magnetic hysteresis clutch to drive the flowmeter rotor at a constant torque has the best prospects for LH_2 mass measurements. The hysteresis drive eliminates the need for a delicate and temperature-sensitive torque pickoff and permits rapid response to flow-rate transients.

Existing techniques for mass flow measurement, while basically applicable to cryogenic fields, must be modified in order to perform at extremely low temperatures. Furthermore, the flowmeter must be capable of maintaining full accuracy in conditions of vibration, in rapid flow transients, rapid changes in temperature, and in the RIFT radiation environments.

In the flowmeter, the expression Mass Flow = $\frac{KT}{\omega}$ relates the fluid torque, T, the fluid angular velocity, ω, and the mass flow rate. Since a single turbine is driven at a constant torque, the speed of the turbine is inversely proportional to mass flow rate. The flowmeter pickoff coil converts rotor

speed to an AC signal having a frequency proportional to rotor speed. A digital or analog type of indicator then converts the AC output signal to a signal acceptable for telemetry. The Waugh Engineering Division of the Foxbore Company has developed such a constant-torque flowmeter which looks very promising. The next step is to evaluate the flowmeter in a combined cryogenic and radiation environment.

1.2.5 Acoustic Level

Acoustic levels on the RIFT vehicle will require minor development. A piezoelectric type of acoustic pickup is currently available which should meet RIFT requirements. This type incorporates a vibration-cancelling scheme.

The unit is currently being used on the Agena vehicle. Only radiation qualification is needed.

1.2.6 Radiation Detectors

1.2.6.1 Inflight Nuclear Measurement System

Nuclear radiation environments will be measured at 18 locations on the nuclear stage, and at each point the fast neutron flux (dose rate) and gamma dose rate will be measured. Thermal neutron flux values will be determined during the captive tests.

The major portion of the measurement points for the inflight stage are located at the propellant tank bottom and about the engine attachment structure to define more accurately the problems of radiation effects on lower tank components

and the heating of propellant and critical structures. The remaining measurement-point locations were chosen within the instrument compartment and atop the propellant tank to enable measurements to be made in the payload region without the effects of air-scattered radiation.

1.2.6.2 Detectors

The range requirements for the detectors are listed in Table 1-5. The prime considerations in the design of gamma and fast neutron detectors are the abilities to measure the specified fluxes and to operate with minimum perturbation in the expected background fluxes. Other considerations are the availability of materials and the stability in radiation, thermal, and vibrational environments. These considerations have led to the selection of ionization chambers for the detection of gamma radiation and fast-fission chambers for the detection of fast neutrons.

Table 1-5

DETECTOR RANGE REQUIREMENTS

Location	Fast Neutrons		Gamma Radiation	
	Flux, $\frac{n}{cm^2\text{-sec}}$	Integrated Flux, $\frac{n}{cm^2}$	Dose Rate, $\frac{r}{hr}$	Dose, r
Engine	10^{11}–10^{14}	10^{14}–10^{17}	5×10^{6}–5×10^{8}	10^{6}–10^{8}
Payload	10^{6} –10^{8}	~ 10^{9}	10^{3}–10^{5}	~10^{4}

1.2.6.3 Gamma Detectors

In order to measure the span of gamma radiation intensities that will be encountered, a family of ion current chambers will be developed. The use of various chamber volumes will reduce the required span of the associated electronics and thereby reduce errors caused by electronics drift. The size of the gamma detectors will range from approximately 0.5-in. diameter by 4 in. length to 2 in. diameter by 6 in. length.

Gamma ionization chambers of the type planned have been in use inside the Savannah River Laboratory reactors. They have given satisfactory performance in a gamma field of $10^9 \frac{r}{hr}$ for long periods.

Some studies and experimentation will be conducted to determine the material suitable for the walls of the chambers. The final selection of material will be a compromise based upon fast-neutron background sensitivity, vibration effects, and the ability to undergo the expected temperature ranges (-60° to $+175^\circ$F) without excessive variations in the density of the filling gas. Argon or carbon dioxide will be used as the filling gas.

Insulation will be a ceramic type that will provide radiation resistance and rigidity. Special attention will be directed toward accurate definition of the sensitive volume of detection. Guard ring type triaxial conductors will be used to minimize ionization in the electrical leads.

The testing and calibration of the detectors will be conducted during the Early NERVA-engine firings. Some additional cross calibrations will be performed at the Radiation Effects Reactor at the Georgia Nuclear Laboratories.

1.2.6.4 Fast-Neutron Detectors

In order to measure the span of fast-neutron flux that will be encountered, a family of fission chambers will be developed. The choice of operation as a gamma-compensated current chamber or as an electron pulse chamber will depend upon the neutron-to-gamma ratio and the gamma dose rate at the location of the detector. Detailed analyses have shown that both types must be used. Analyses have indicated that in the regions of highest expected gamma fluxes the neutron signal to gamma noise ratio will be too low for operation of a fast fission pulse chamber with its necessarily thin film of fissionable material and high biasing against gamma noise. However, in these regions it will be possible to use a gamma-compensated fission current chamber – since, with the expected ratio of neutron to gamma flux, the use of the maximum thickness of fissionable material will give a fission current to gamma current ratio of approximately five. Gamma compensation will be accomplished by the usual method of automatic subtraction of the current from a similar chamber without fissionable material.

In the regions of lower fluxes, the neutron to gamma ion current ratio will be reduced to a value of one or less, so that the use of a gamma-compensated fission current chamber is not practical. However, the gamma background there is low enough to permit the use of pulse-type fast-fission chambers of various sizes with thin films of fissionable material and nonexcessive bias against gamma noise.

Analysis indicates that, in the regions of high neutron to gamma ratios, thorium-232 can be used as a fissionable material, but in the regions of low neutron to gamma ratios it might be necessary to use neptunium-237. Plutonium-239 shielded with boron-10 will be considered as an alternate material if neptunium-237 is not available in sufficient quantities.

The ratio of fission to gamma heating in a fission thermopile detector at the expected ratio of neutron to gamma flux does not make this type of instrument appear as promising as types mentioned earlier, but experimental work on gamma-compensated fission thermopiles will be performed as an alternate approach to fast-neutron detection.

1.2.6.5 Electronic Circuitry

The range requirements outlined in Table 1-5 dictate that the electronic circuitry monitor the output from the detectors over a three-decade span for fast-neutron measurements and over a two-decade span for gamma. Because two decades may be read out with sufficient accuracy on a linear scale, the drift and calibration problems inherent in log-responding micromicroammeters can be avoided in the gamma channels. Since the neutron detectors will be both gamma-compensated current chambers and electron-pulse chambers, both current and pulse-type circuitry will be required. The three-decade span makes mandatory the use of logarithmic scales or the adoption of some automatic means of selecting the proper range setting of the instruments. The packaging design will permit the installation of the circuitry in the instrument compartment, but long cabling will be required to convey signals from detectors and preamplifiers located at various points on the vehicle.

1.2.6.6 Gamma Channel

Figure 1-2 is a block diagram of the gamma instrumentation. Since this is a current-measuring instrument, preamplifiers will not be required. Detailed design of the circuitry will depend on the signal current levels which the final detector design will provide, and a brief experimental program to determine what type of input circuitry will be satisfactory at the supplied current levels in the prescribed environment.

Since the equipment is designed for a short operating life, chopper stabilization and other more sophisticated techniques can probably be avoided. In this case, the micromicroammeter will take the form of an operations amplifier. This configuration, in addition to its simplicity, offers the advantage of low input impedance (which is very desirable in view of the long detector leads) and relative freedom from drift. The extremity of the environment, however, may force the adoption of a more extensive effort to obtain a satisfactory degree of stability.

1.2.6.7 Neutron Channel

A block diagram of the neutron-measuring circuitry associated with the pulse-type detectors is shown in Fig. 1-3. This detector will require a preamplifier to match its high output impedance to the low input impedance of the cable to the instrumentation. The preamplifier will be either a simple cathode follower or some other form of 100-percent-feedback circuit configuration so that any radiation-induced changes in circuit parameters will result in minimum

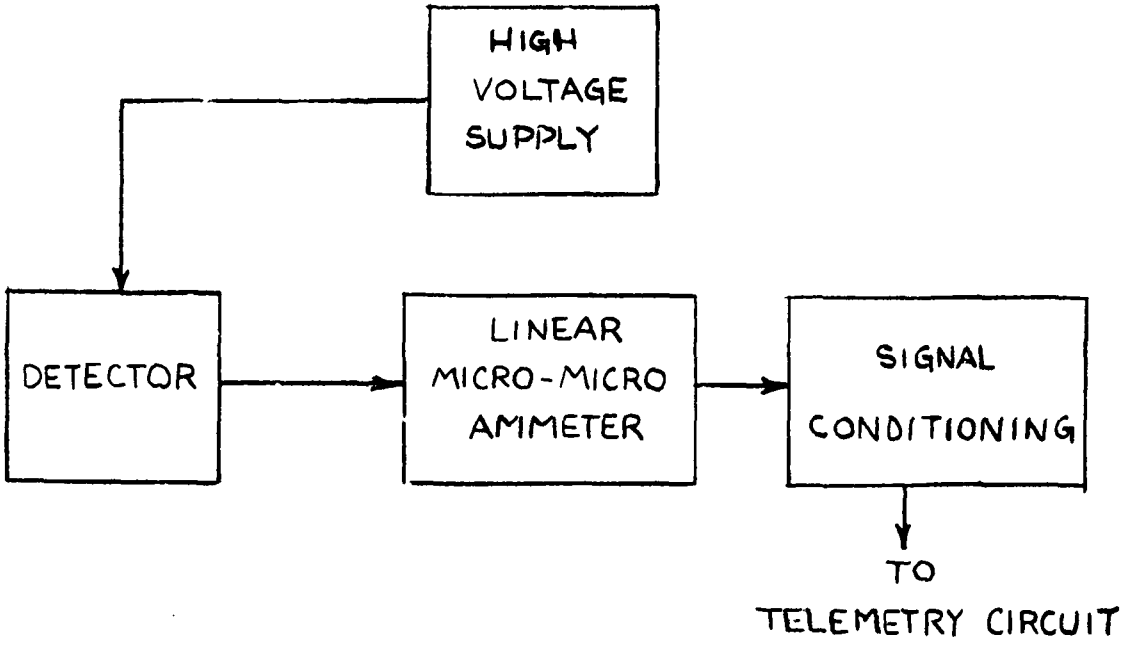


Fig. 1-2 Block Diagram of Gamma Channel

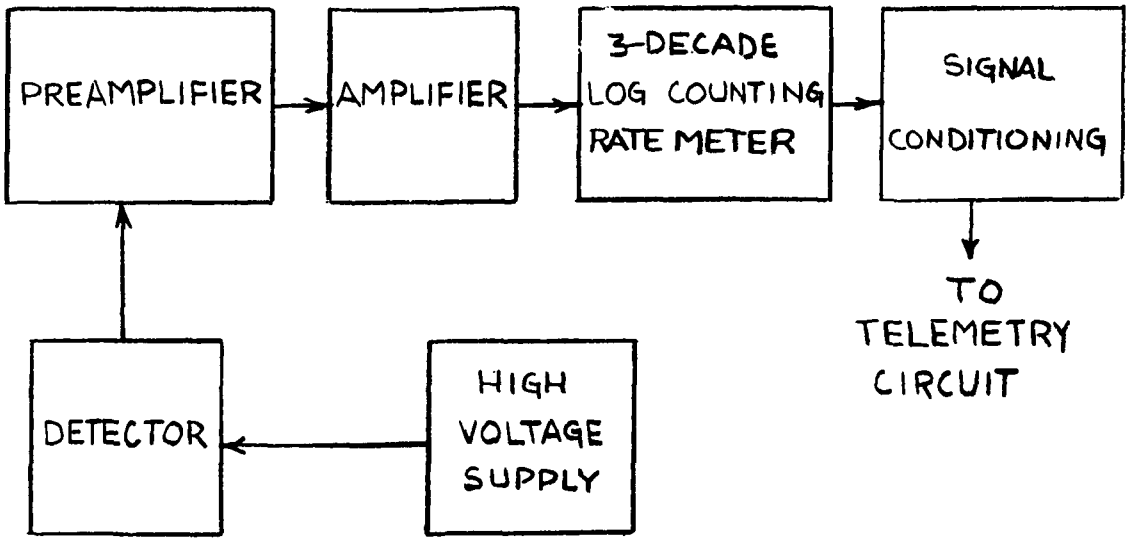


Fig. 1-3 Block Diagram of Inflight Nuclear Measurement Circuitry

changes in amplifier performance. Subminiature vacuum tubes appear to be the elements best suited for the amplifying elements in the preamplifier circuitry.

There are several widely used methods for obtaining a signal proportional to the logarithm of a counting rate. These include nonlinear diode pump circuits and the use of R-C-diode charging circuits. Lockheed has developed a log-counting rate meter for use in the area monitoring system at the Georgia Nuclear Laboratory at Dawsonville which employs a modified one-shot multivibrator to obtain a current proportional to the log of the input counting rate. This instrument has proved reliable and relatively drift-free for an operating period of over 3 years. If the log circuitry proves unable to maintain calibration under the vehicle operating conditions, a linear system which automatically selects the proper range for most accurate operation will be considered. A block diagram of such a system is shown in Fig. 1-4. This system employs two gates and a diode logic circuit to determine which one of three linear counting rate meters will receive the output pulse from the input multivibrator. The full-scale output current (or voltage) from all linear count-rate meters would be equal. A second channel of telemetry operated by the gate circuits would be required to determine which of the three counting-rate meters was supplying the signal at a particular time.

The block diagram for the circuitry to be used with the gamma-compensated current chamber will be similar to that of the gamma channel shown in Fig. 1-2 except that the current measuring will be logarithmic. The circuitry will employ a nonlinear feedback element in an operations amplifier configuration to obtain the required log response.

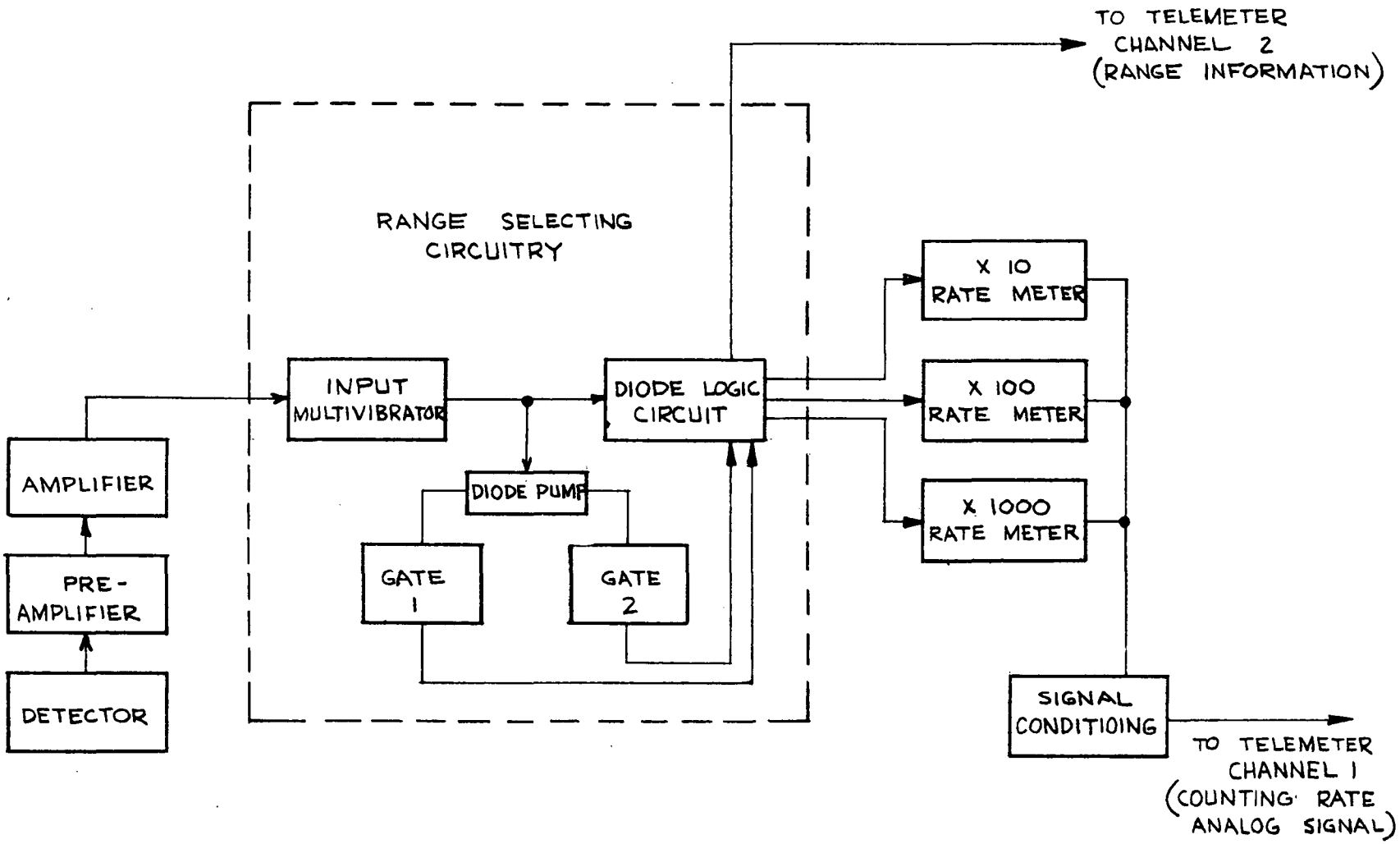


Fig. 1-4 Block Diagram of Three-Decade Automatic Range Selecting Circuit for Neutron Channel

1.2.6.8 Solid-State Radiation Detectors

Recent development in solid-state electronics has produced radiation detectors and spectrometers very attractive to airborne application.

The small size and low power and voltage requirements for these detectors make them very well suited for RIFT air and ground applications.

1.2.6.9 Neutron Detector

Two basic approaches are available in the design of a solid-state neutron detector:

(1) Direct interaction between silicon and neutrons in a p-n junction

(2) Detection by use of secondary particles absorbed in a p-n junction

The direct-interaction method for fast neutrons is limited to neutrons with energy levels above 4 to 5 Mev. The protons released by the reaction Si^{28} (n,p) Al^{28} are then absorbed directly in the detector depletion region.

The secondary particle type of detector utilizes an external radiator to generate charged particles. Neutron reaction in this radiator results in an emission or scattering of heavy charged particles which will be absorbed in the detector depletion region. The external radiator consists of a thin coating on the detector of B^{10} or Li^{6}. This arrangement will permit detection of neutrons in the energy range of 0.26 Mev to approximately 5 Mev where the direct interaction between silicon and neutrons will occur.

1.2.6.10 Gamma Detector

Gamma-ray detection can be accomplished by subtraction methods using two detectors, one of which is detecting both neutrons and gammas and one which is detecting only neutrons.

1.2.6.11 Output Characteristic

The output from the p-n junction type detector is in the form of a voltage pulse for each reaction or particle absorbed in the depletion region. Ranges of flux up to 10^{10} nv are hopefully possible, the limit being the required preamplifier response. The temperature of the detector is limited to +150°F. By employing cooling techniques much the same as in infrared detector design, a higher range of temperature can be obtained. The pulse height is directly proportional to the energy of the incident neutrons. Direct measurement of energy distribution of the incoming neutrons is thus possible.

It appears feasible at the present time to develop a detector-preamplifier combination with a volume of less than 2 cu in. The size of such a unit will permit location of measuring points inside the LH_2 tank for measurement of fuel heating due to radiation. Obviously, vacuum insulation of the unit must be employed to protect the electronics from the low temperature.

1.3 TRANSDUCER-EVALUATION PROGRAM

A very extensive transducer-evaluation program is planned for the RIFT Program. This evaluation program will encompass those types of measuring devices presently

scheduled and all future transducers which might be used. Continual evaluation of new types of transducers will maintain the state-of-the-art. Transducer types anticipated for test at this time are listed in the following table:

Parameter	Type of Transducer
Pressure	Potentiometer (bourdon tube and bellows) Unbonded strain gage Differential transformer Variable reluctance Piezoelectric
Acceleration	Potentiometer Gas-damped unbonded strain gage Oil-damped unbonded strain gage Differential transformer Servo type
Vibration	Piezoelectric (barium titanate) Piezoelectric (lead zirconate titanate) Piezoelectric (quartz) Note: The bender, compression, and shear-mode types will be included in the above three vibration transducers.
Temperature	Thermocouples (Chromel-Constantan and tungsten-tungsten 26% rhenium) Platinum resistance thermometers Thermistors Piezoelectric
Position	Potentiometer Differential transformer
Flow Rate	Mass type – constant torque Mass type – volumetric with temperature compensation
Strain	Unbonded SR-4 type High gage-factor type
Rate (RPM)	Magnetic pickup
Sequence	Switches

Parameter	Type of Transducer
Acoustic	Piezoelectric Capacitance Dynamic
Radiation	Solid-state p-n junctions Ionization chambers Fast-fission chambers
Rate (deg/sec)	Velocity pickup
Liquid Level	Acoustic type (continuous) Point sensors (acoustic, light, magnetostrictive) Capacitance (continuous)
Thrust	Load cells
H_2 Leak Detector	To be developed

An extensive, thorough survey is now underway to determine transducers suitable for these evaluation tests. A "weeding out" process will eliminate those transducers which are not applicable. Approximately three units from the remaining manufacturers (two or three) will then be subjected to the evaluation program.

The evaluation program will include the following kinds of tests:

- Pre-environmental Tests (at ambient conditions)
  - (1) Insulation resistance
  - (2) Output impedance
  - (3) Linearity
  - (4) Hysteresis
  - (5) Repeatability
  - (6) Resolution

  } Calibration

- Environmental Tests
  - (1) Radiation
    - (a) Forward tank levels
    - (b) Aft tank levels
  - (2) Vibration
  - (3) Shock
  - (4) Acceleration
  - (5) Temperature
    - (a) Cryogenic
    - (b) High
  - (6) Humidity
  - (7) Altitude
  - (8) Combined crogenic and radiation tests are anticipated

Calibration runs will be made during and after each type of environmental test to determine performance under that particular environment. Based upon these evaluation results, specific types and manufacturers will then be specified for the RIFT vehicle.

As a typical example of the transducer status, the strain-measuring transducer will be closely examined.

One strain gage planned for use on the RIFT stage is the Microdot LL-E-4D weldable strain gauge. The present unit is usable over a temperature range of $-320^{\circ}F$ to $+750^{\circ}F$ and is presently being used in radiation environments by the following agencies:

- Savannah River Atomic Energy Project
- University of California Radiation Laboratory, Livermore, Calif.
- Phillips Petroleum Co. Atomic Energy Division, Idaho Falls, Idaho
- Nuclear Systems, Idaho Falls, Idaho

The gage consists essentially of a fine wire (N~0.001 in.) surrounded by a high-temperature metallic oxide insulating powder, which in turn is encapsulated in a metallic tubular shell. The tube is swaged over its entire length to compress the powder and clamp the wire. A mounting flange is spotwelded to the tube to facilitate mounting of the gage to the structure by spotwelding. The strain is transferred through the flange into the tube and, by means of the compressed powder clamp, the strain will be imposed on the fine resistance wire. The gage can be used in two basic configurations:

(1) Two active gages and two dummy gages all located in the measurement area and connected in a Wheatstone bridge connection

(2) A single gage located in the measuring point and connected to a Wheatstone bridge at a remote location

The first connection will provide both temperature and radiation compensation provided temperature and radiation distribution is uniform in the measuring area. The second connection will provide temperature compensation if the gage thermal expansion is similar to that of the structures. The Microdot gage can be compensated to a specific structure material to a tolerance of ±50 μin. per in. at 600°F.

Connection No. 1 will be used in areas where the radiation level is high and where the temperature might fluctuate rapidly. Connection No. 2 will be used in areas of stable temperature and low level of radiation.

The test status of the Microdot gage is as follows. Complete evaluation has been performed by LMSC at elevated temperature. A summary of this evaluation is shown in Table 1-6. A radiation dose test has been performed on the unit. A radiation level of 10^{18} nvb did not produce detectable damage. An investigation of the low-temperature performance must be conducted before application in the cryogenic environment. The program for this test is outlined as follows:

(1) Install compensated gages on test strips of RIFT tank material.

(2) Test the gages under tension at temperatures from 0 to -424°F. Investigate at least four points in this temperature range.

(3) Determine the following parameters during these tests:

  (a) Apparent strain vs. temperature

  (b) Apparent strain vs. driving current

  (c) Sensitivity vs. temperature

  (d) Linear range vs. temperature.

(4) Repeat tests (1) through (3) using four uncompensated gages mounted on the tension strip. Mount the dummy gages in such a way that no strain will be transferred to the gages. The thermal conduction path of the active and dummy gages will be similar.

Table 1-6

SUMMARY TEST DATA

Item	Gage #1		Gage #2		Gage #3		Gage #4	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
Cross-sectional Area of Coupon (in.)	0.125 by 0.64		0.125 by 0.64		0.064 by 0.643		0.064 by 0.643	
Nonlinearity (%)	+1.9	+2.1	-1.4	+0.4	-1.3	+0.4	+0.4	-0.7
Nonrepeatability	—	Runs 2, 3, & 4, 0.8%	—	Runs 2 & 3, 0.3%	—	Runs 2, 3, & 4, 0.4%	—	Runs 2, 3, & 4, 0.2%
Apparent Strain Due to Temperature (on 4130 steel)	535 µin./in. @726°F	455 µin./in. @623°F	1037 µin./in. @622°F	528 µin./in. @607°F	495 µin./in. @614°F	437 µin./in. @589°F	246 µin./in. @598°F	183 µin./in. @592°F
Hysteresis, incl. coupon material (%)	-0.9	-0.6	-2.0	+0.3	+1.4	-0.8	+2.2	-0.9
Thermal Hysteresis	426 µin./in. @500°F	173 µin./in. @500°F	116 µin./in. @200°F	101 µin./in. @400°F	76 µin./in. @300°F	79 µin./in. @400°F	95 µin./in. @500°F	78 µin./in. @400°F

LOCKHEED MISSILES & SPACE COMPANY

1.4 CALIBRATION

1.4.1 Proposed Calibration Method

LMSC proposes the substitution of a known percentage full-scale device voltage or current for both on-pad and inflight calibration where this is technically feasible. The obvious advantage of this type of calibration will be weighed against the added weight involved for inflight testing. Calibration will be accomplished by microminiature relays switching lightweight devices across transducer outputs in signal conditioning modules. Using this system, calibrations can be commanded by communications link, umbilical cable, or manually at the vehicle. High-speed data gathering systems can be programmed to command prefire and postfire automatic calibrations as a part of launch and ground test procedures. Figure 1-5 details a proposed system block diagram.

1.4.2 Flight Measurement Summary

The following measurements are currently specified for flight and ground testing:

Transducer Type	No. Measurements
Potentiometer Transducers	133
Thermocouples – 45 rhenium/tungsten, 127 Chromel/ Constantan	172
Resistance Temperature Thermometers – Platinum	115
Bonded Strain Gage	186
Unbonded Strain Gage	64
Piezoelectric (vibratory and acoustic)	11
Total	681

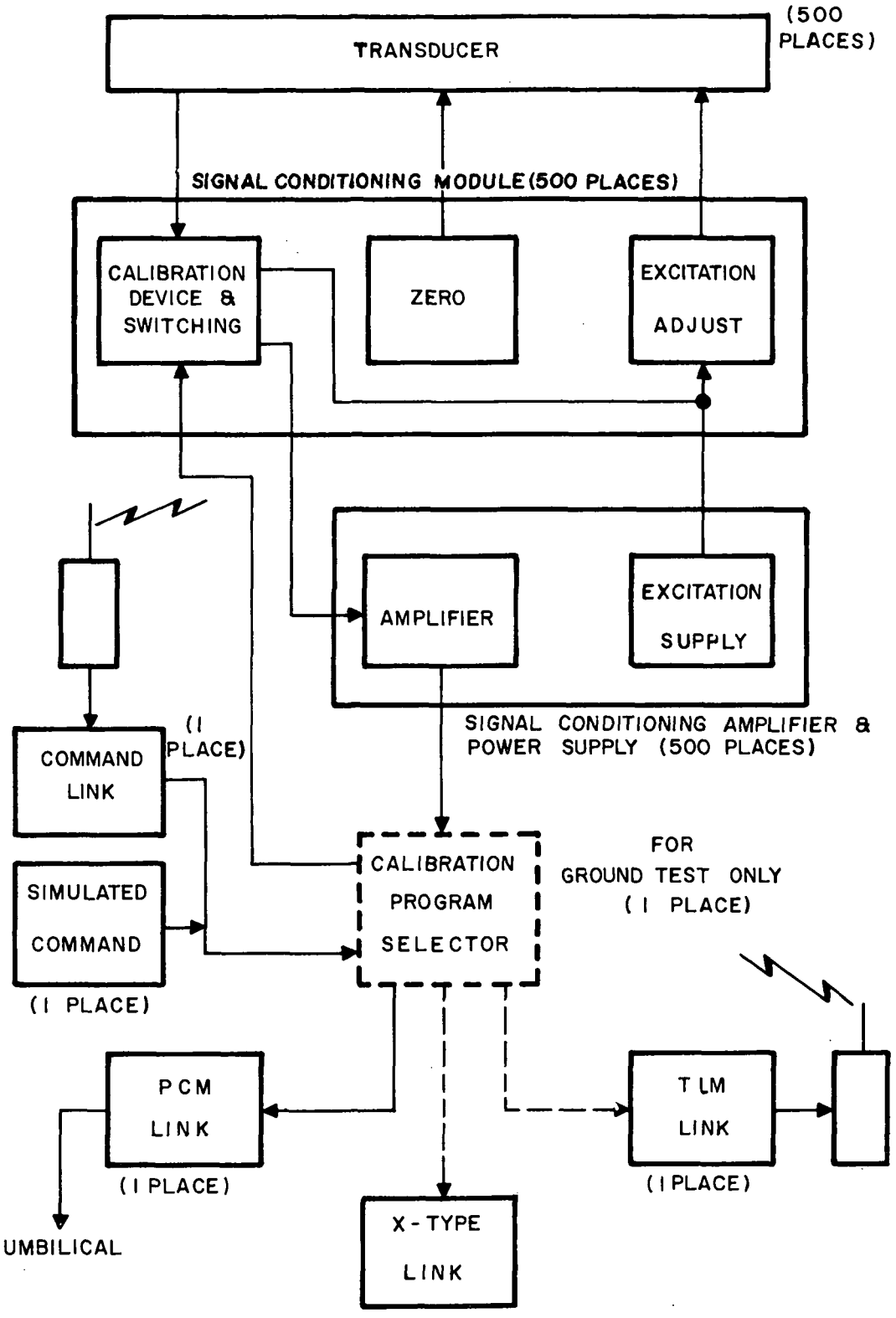


Fig. 1-5 Calibration System Block Diagram

These measurements will require at least 500 signal conditioners and 500 signal-conditioning modules. A total of 1,029 measurements are specified currently. Calibration circuitry and procedure must be such that all channels can be calibrated immediately prior to captive test or launch in a minimum of time. Practically speaking, provision must also be made for system calibration of selected points.

1.4.3 Calibration Program Selector

The calibration program selector (Fig. 1-5) is proposed to provide maximum captive-test calibration flexibility. The unit will be removed for flight test and a prewired unit substituted which will select only those transducer channels required for the flight. This unit will select only; a command (or a simulated command) from the command link will be required to calibrate those transducers selected. In addition, this unit will select a particular vehicle-to-ground data transmission path. The program selector will provide a design tie-point for signal-conditioning amplifier outputs, signal-conditioning module switching inputs, command inputs, and various types of data-output transmission paths. As such, it will allow measurement-system design to proceed before final design inputs on data transmission paths are available.

1.4.4 Bridge-Type Transducers

The common resistor substitution method of bridge calibration will be used, the exact method depending upon the length of wires between transducers and calibration resistors. It has been shown that a calibration error of $4R_L/R$

exists in a four-wire system ($R_L = \frac{\text{lead resistance}}{2}$, R = bridge resistance), $2R_L/R$ in a five-wire system, and zero calibration error in a six-wire system. It would be desirable, therefore, to specify bridge transducers with six-pin outputs to minimize calibration error. However, such a specification conflicts with weight requirements. Bringing the calibration resistor physically as close as possible to the transducer conflicts with space and modular design requirements. An analysis of these factors follows.

1.4.4.1 Error Analysis

Maximum S-N Stage lead length is ~100 ft based upon calibration modules and signal-conditioning equipment located at station 3443 with transducers at station 2483. The possibility of longer lead lengths is also considered — for example, transducers at S-IC Stage station 200 with associated calibration resistors at station 3443. Table 1-7 presents wire characteristics for 350-ohm bridge transducers and standard annealed bare copper wire at 20°C.

Table 1-7

WIRE CHARACTERISTICS
(350-ohm bridge transducers, standard annealed bare copper wire, 20°C)

Wire Size (AWG)	RL (ohm/100 ft)	Weight (lb/100 ft)				Calibration Error (%)	
		Single	4-wire	5-wire	6-wire	$4R_L/R$	$2R_L/R$
18	0.6385	0.4917	1.967	2.458	2.950	0.73	0.36
20	1.015	0.3092	1.237	1.546	1.855	1.1	0.55
22	1.614	0.1945	0.7780	0.9725	1.167	1.8	0.90
24	2.567	0.1223	0.4892	0.6115	0.7338	2.9	1.4

An engineering compromise between tolerable added weight and R_L/R calibration error must be made in the case of 100-ft separation between transducers and calibration resistors. If an arbitrary maximum calibration error of 1 percent is chosen, a wire size between 18 and 20 AWG is indicated. Solution of the equation $4R_L/R = 0.01$ provides a more exact wire size between 19 and 20 AWG. Wire lengths greater than 100 ft introduce errors exceeding the specified maximum. In general, it appears that wire sizes larger than AWG 20 introduce undesirable calibration errors while those smaller than AWG 20 introduce undesirable added weight in four-wire calibration systems.

1.4.4.2 Solutions

Alternate solutions derived in the analysis are as follows:

- Solution No. 1. Neglect the possibility of lead lengths greater than 100 ft, install five-wire systems, and trade a 25-percent weight increase for a calibration error of 0.90 percent using standard AWG 22 wire.
- Solution No. 2. Admit the possibility of lead lengths greater than 100 ft and install six-wire systems utilizing AWG 24 wire, trading a 5.6-percent weight decrease for the reduced physical integrity of smaller wire. The loop resistance of 300 ft of AWG 24 wire is ~ 15 ohm and the maximum required DC current load per transducer is $\sim \frac{10}{350} = 28.6$ ma; therefore, the IR drop is approximately 15 x 0.0286 = 0.43 v, which can

be compensated. R_L/R calibration error for this system would be zero for all transducers.

- Solution No. 3. Install tape cable six-wire systems saving 80 percent in weight for the same current capacity. A tape cable system using AWG 18 wire would weigh less than such a system with equivalent current-carrying capacity but using AWG 24 wire. R_L/R calibration error would be zero for all transducers.
- Solution No. 4. Eliminate the R_L/R error by procuring all flight transducers with integrally mounted calibration resistors and switching devices. This solution is technically feasible, as all transducers can be specified with nominal 350-ohm bridge circuits and standardized calibration resistors. No overall weight increase is involved; however, there are size and procurement problems. Six-wire tape cable could be used with this configuration – two wires for relay control.

1.4.4.3 Tape Cable Technical Data

Tape cable (unshielded) has the following advantages: high conductor density per cross-section square inch, 80-percent weight reduction, 80-percent space reduction, low and uniform interconductor capacitance of less than 5 $\mu\mu$f/ft between conductors, 90-percent reduction in installation costs, high tensile strength, tear resistance, ruggedness, chemical inertness, and high flex life. There appear to be two disadvantages: cable to transducer termination

mismatches (physical) and shielding complexity. The latter is probably the easier to solve.

1.4.4.4 Preferred Solution

Solutions 3 and 4 require long-range developmental effort and will be pursued. Solutions 1 and 2 are entirely within the present state-of-the-art. Solution 3 is preferred and is proposed. Pending results of vendor development effort, Solution 2 will be held in reserve. Solution 1 is not acceptable.

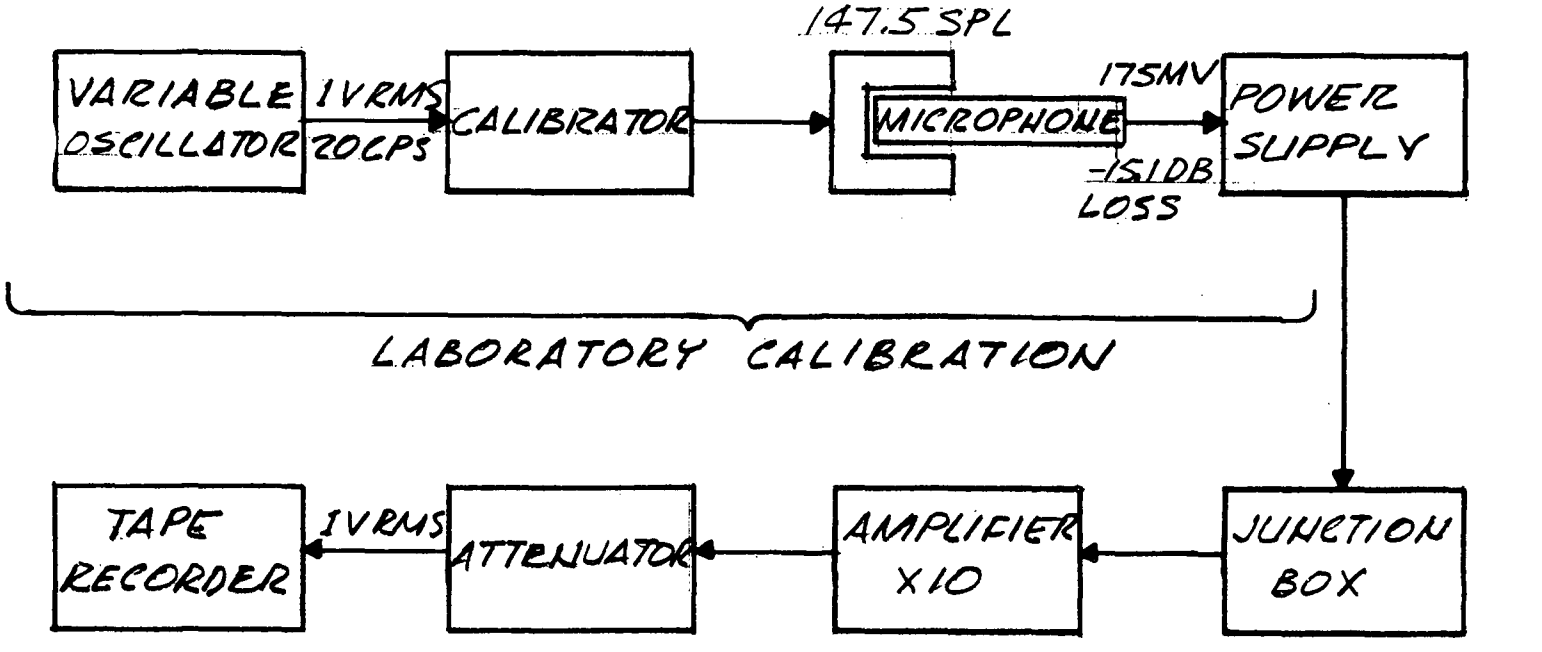
1.4.5 Specialized Systems

Acoustic levels, radiation detection, acceleration, and vibration are considered specialized systems for the purpose of this presentation.

1.4.5.1 Acoustic Level

Calibration (and checkout) involves setting up a specified sound pressure level (SPL) at the pickup microphone and attenuating the resultant amplified output to some specified level such as 1 v rms at the input to a tape recorder. Basic microphone sensitivity is defined as output volts in db referenced to 1 v for an SPL of 74 db (1 microbar = 10^{-6} = 1 dyne/cm^2 = 74 db SPL). System calibration does not adapt easily to high-speed methods if reasonably accurate data reduction is desired. Fortunately, few acoustic-level measurements are presently required.

Based on these factors, no specific method of high-speed acoustic-level channel calibration is being proposed at this time. Figure 1-6 details a typical



MICROPHONE SENSITIVITY = OUTPUT VOLT IN db REFERENCED TO 1 VOLT FOR SPL OF 74 db

SOUND SENSITIVITY SYSTEMS = 147.5 + 15.1 - 74.88 db AT 20 CPS

SPL = SOUND PRESSURE LEVEL

Fig. 1-6 Typical Acoustic-Level Calibration System

acoustic-level calibration system in use at an LMSC test facility. Note that this involves essentially a laboratory procedure.

1.4.5.2 Radiation Detection

Calibration of radiation-detection channels typically involves substitution of known currents for the output of fission chambers and low-level detectors. Startup rate calibrations typically are accomplished by feeding known ramp inputs to low-level channels. The uncertainty connected with neutron detector deterioration with time is typically resolved by cross-checks against other physical phenomena connected with the reactor. A standard precaution, used for both system calibration and reactor cold startup, is the insertion of a neutron- or gamma-producing source of known strength in the vicinity of the nuclear core or in the core.

Inasmuch as the electrical calibration of a nuclear radiation detection system can be accomplished within the readout portions of the equipment (if primary sensor calibration is accomplished in the laboratory), no calibration channels are being proposed for S-N Stage radiation detectors. Ramp functions for startup rates and simulated fission-chamber current levels will be generated within readout equipment racks. Overlapping startup and power range decade scales will provide a calibration cross-check between ion and fission chambers. Proper installation and use of gamma and neutron sources will provide low-level startup protection and calibration.

1.4.5.3 Acceleration and Vibration

System calibration procedures typically involve feeding a range of known frequencies and voltage levels into test-stand primary-sensor termination points. The calibration program is usually automatic. A correction factor for cable capacitance between the primary sensor and the calibration signal injection point is introduced into data-reduction procedures. Use of space charge amplifiers makes this latter procedure unnecessary for certain primary sensors. A primary sensor system consisting of sensor, cable, and amplifier is often laboratory-calibrated before mounting on the vehicle. All accelerometers and vibration pickups are laboratory-calibrated prior to vehicle installation.

Inasmuch as system calibration procedures generally are directed toward calibration of land-line cabling and end-instrumentation, no specific onboard acceleration and vibration calibration instrumentation is proposed in excess of the standard transducer bridge inflight calibration modules, which can be used to calibrate bridge type accelerometers.

1.5 CHECKOUT

The laboratory procedure used for calibration of all types of transducers will also constitute a unit checkout prior to mounting on the vehicle. Complete system checkout will be accomplished by the general calibration procedures set forth in Subsection 1.4.1. General procedures for calibration and checkout of specialized systems such as acoustic level and radiation detection are described in Subsection 1.4.5.

1.6 SIGNAL CONDITIONING

1.6.1 General Considerations

All signal conditioning will be accomplished at a single location near station 803. Signal-conditioning modules will be miniature printed circuit plug-in units for system flexibility. Millivolt signals will be raised to a 0–5 v range by stabilized DC amplifiers with adjustable excitation voltages provided for the transducers. Figure 1-7 details proposed packaging methods.

Signal conditioning module schematics are shown in Figs. 1-8, 1-9, and 1-10. Thermocouple signal conditioning is accomplished by automatic compensation for cold-junction temperature by a temperature-sensitive resistor in series with the thermocouple signal.

Other types of transducers, such as accelerometers and radiation detectors, with high-frequency outputs will have separate terminating amplifiers with 0–5 v output.

The normal equipment-mounting method will use bolts fixed through mounting holes or slots in equipment base plates. Electrical connections normally will be made to connectors mounted on one end of the equipments. An exception to the normal method of electrical connection by flexible cable and plug is recommended.

The signal-conditioner units and multiplexer units of the data system will have many hundreds of wires in the connectors. Because of the large number

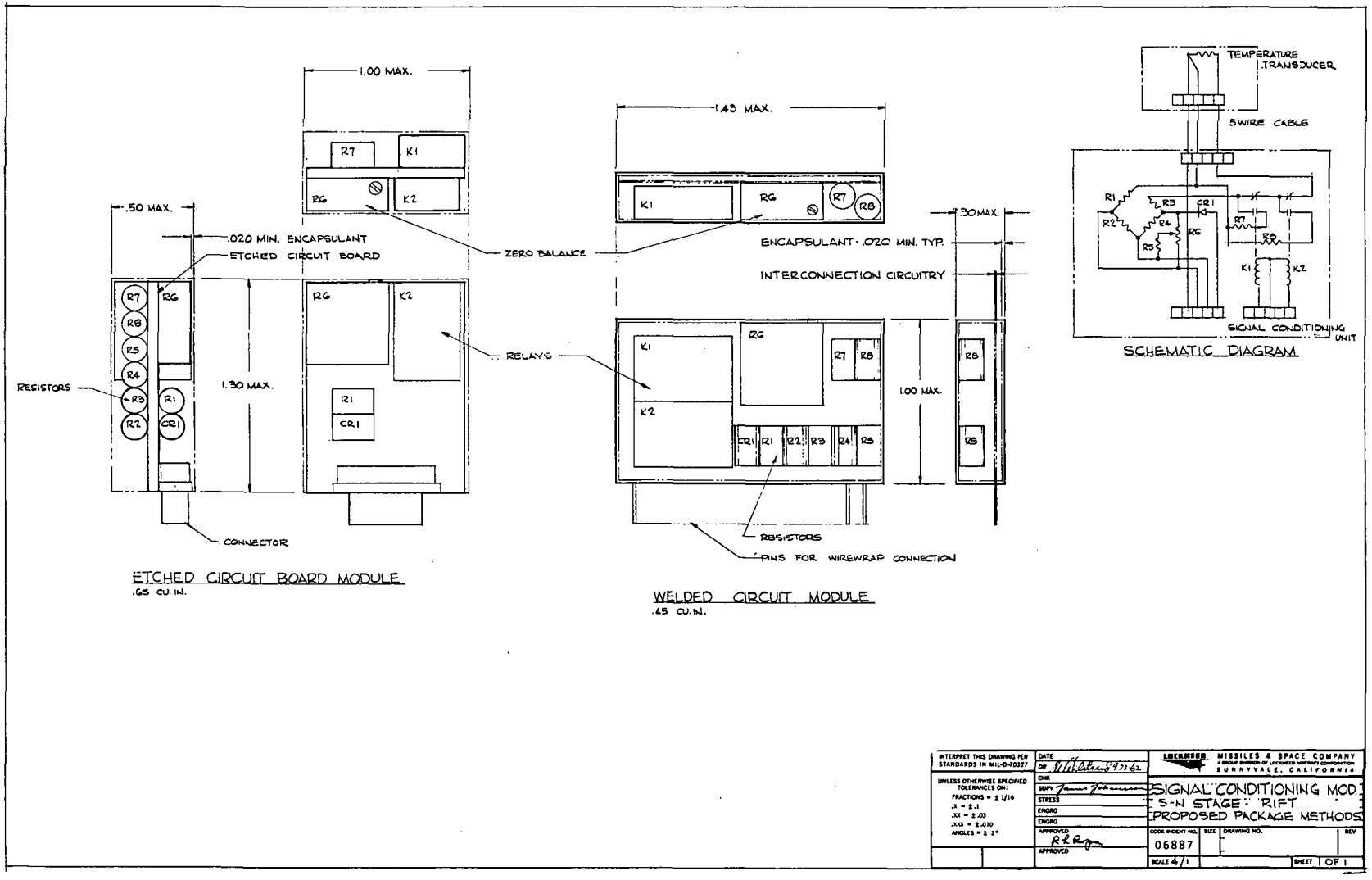


Fig. 1-7 Signal-Conditioning Module, S-N Stage — Proposed Package Methods

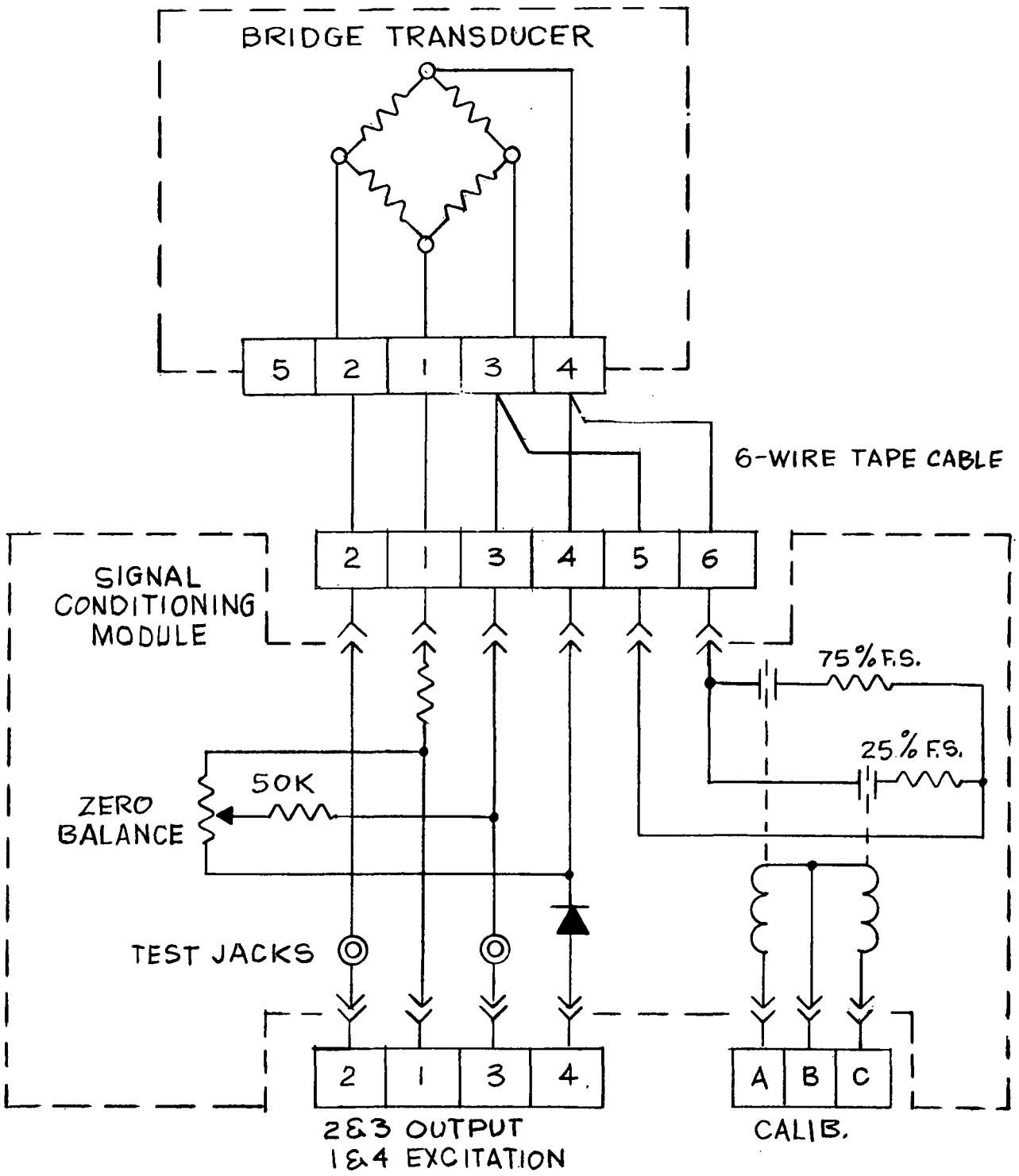


Fig. 1-8 Bridge Signal-Conditioning Module

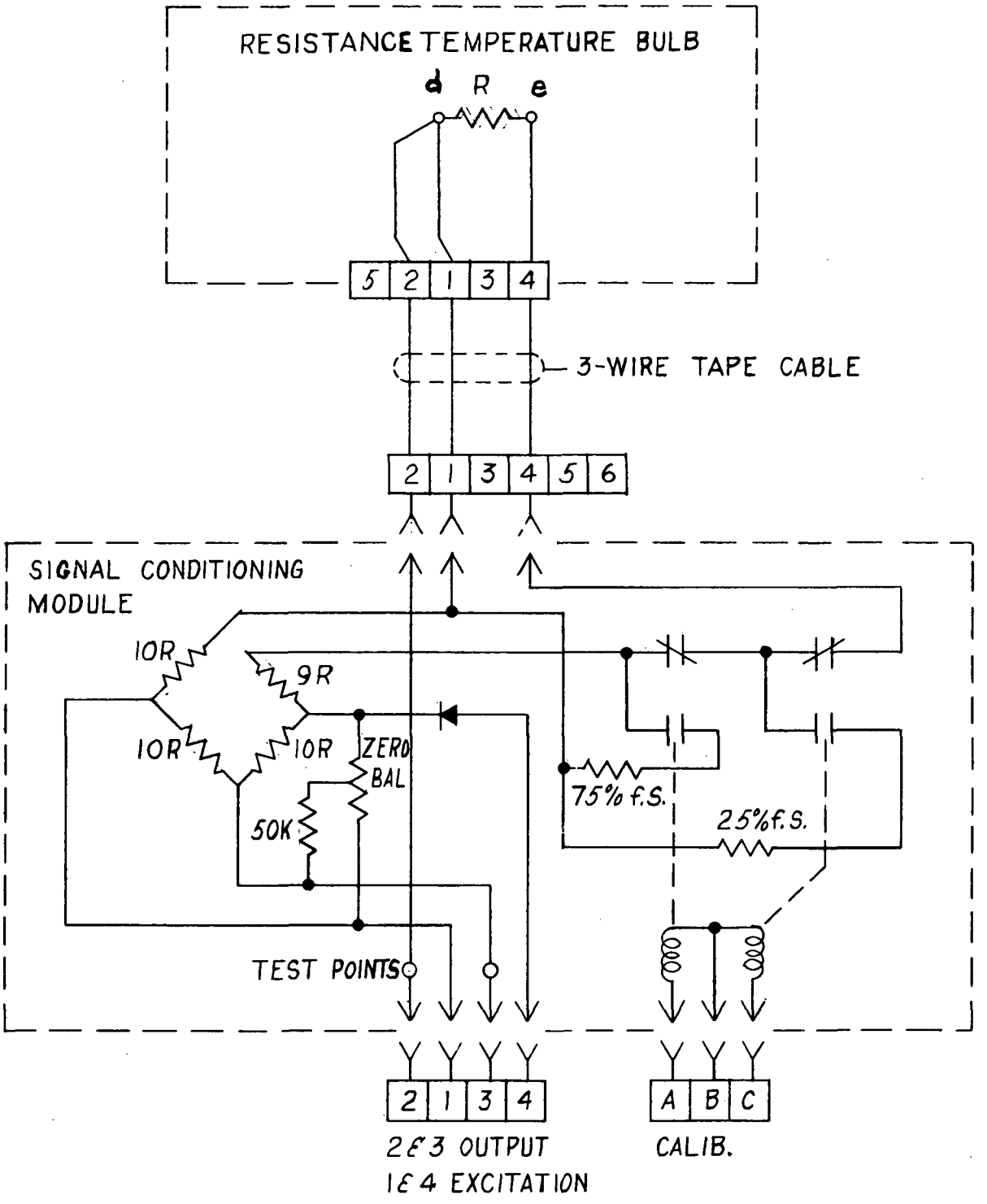


Fig. 1-9 Temperature Signal-Conditioning Module (RTB)

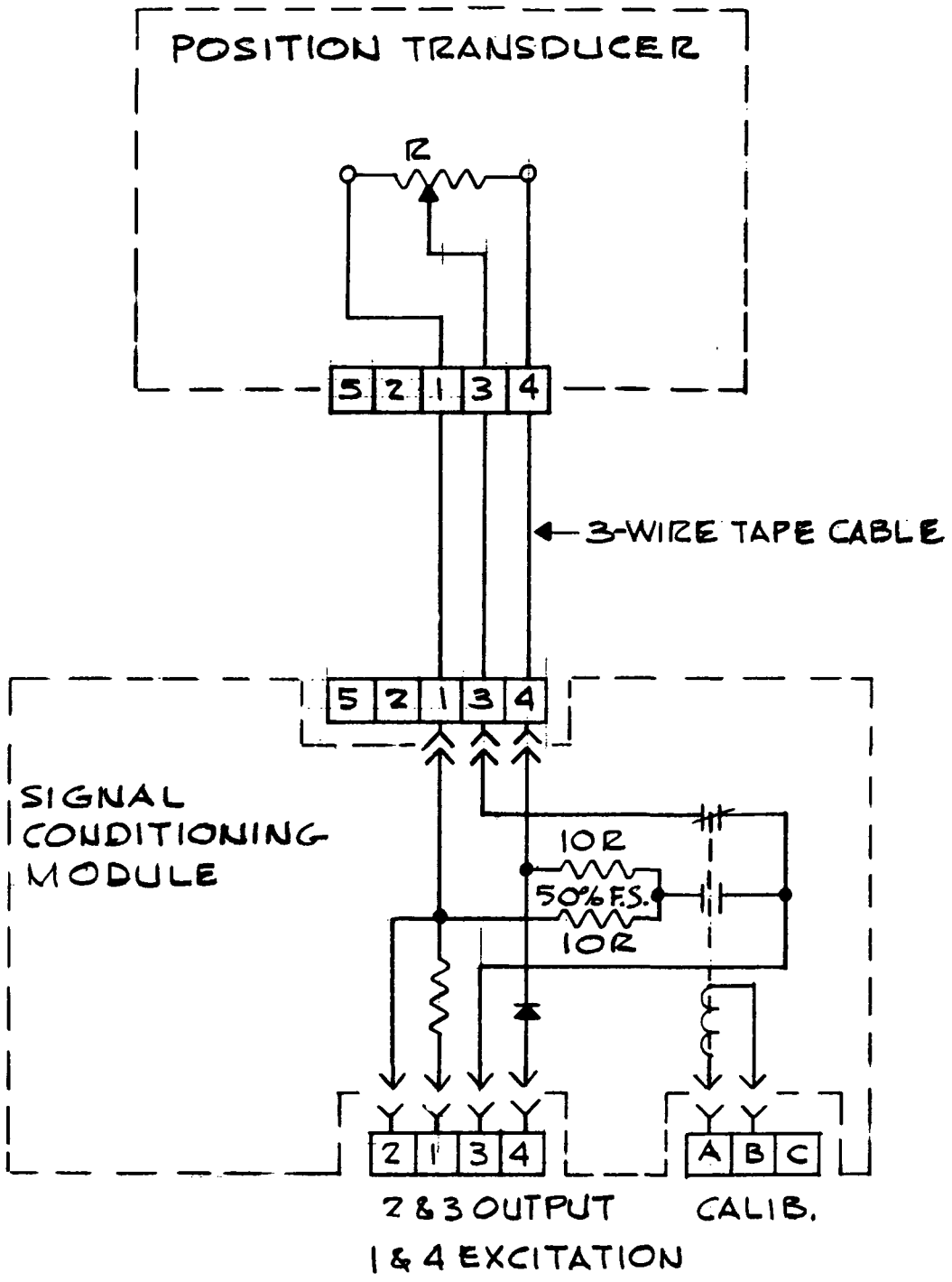


Fig. 1-10 Position Signal-Conditioning Module

of wires involved, it is recommended that the multiple connections to these units be fixed in relation to the vehicle frame and that provision be made for "plugging in" the equipments prior to boltdown. Figure 1-11 illustrates a proposed method.

The equipment rods contain a set of multiple contacts fixed in position on a connector plate. Signal wiring connects these contacts to the signal transducers located throughout the vehicle.

A set of floating contact male connectors is mounted in the end of the signal-conditioning unit (SCU). The equipment rack also includes guide rails which facilitate alignment of connectors when the SCU slides into mating contact with the connector plate. At this time, the SCU is fixed in position by means of bolts. A second set of connectors is mounted on the near end of the SCU. The multiplexer contains a set of floating contact male connectors on the far end which mate with the SCU when the multiplexer slides into contact with the SCU. The multiplexer is now bolted into position, and power and output connections may be made at this time in the usual manner by flexible cable.

The handling, repeated flexing, and possible failure of bulky, multiple (several hundred) conductor cables can be reduced by use of this method of making connections.

A possible signal-conditioning module configuration is shown in Fig. 1-7.

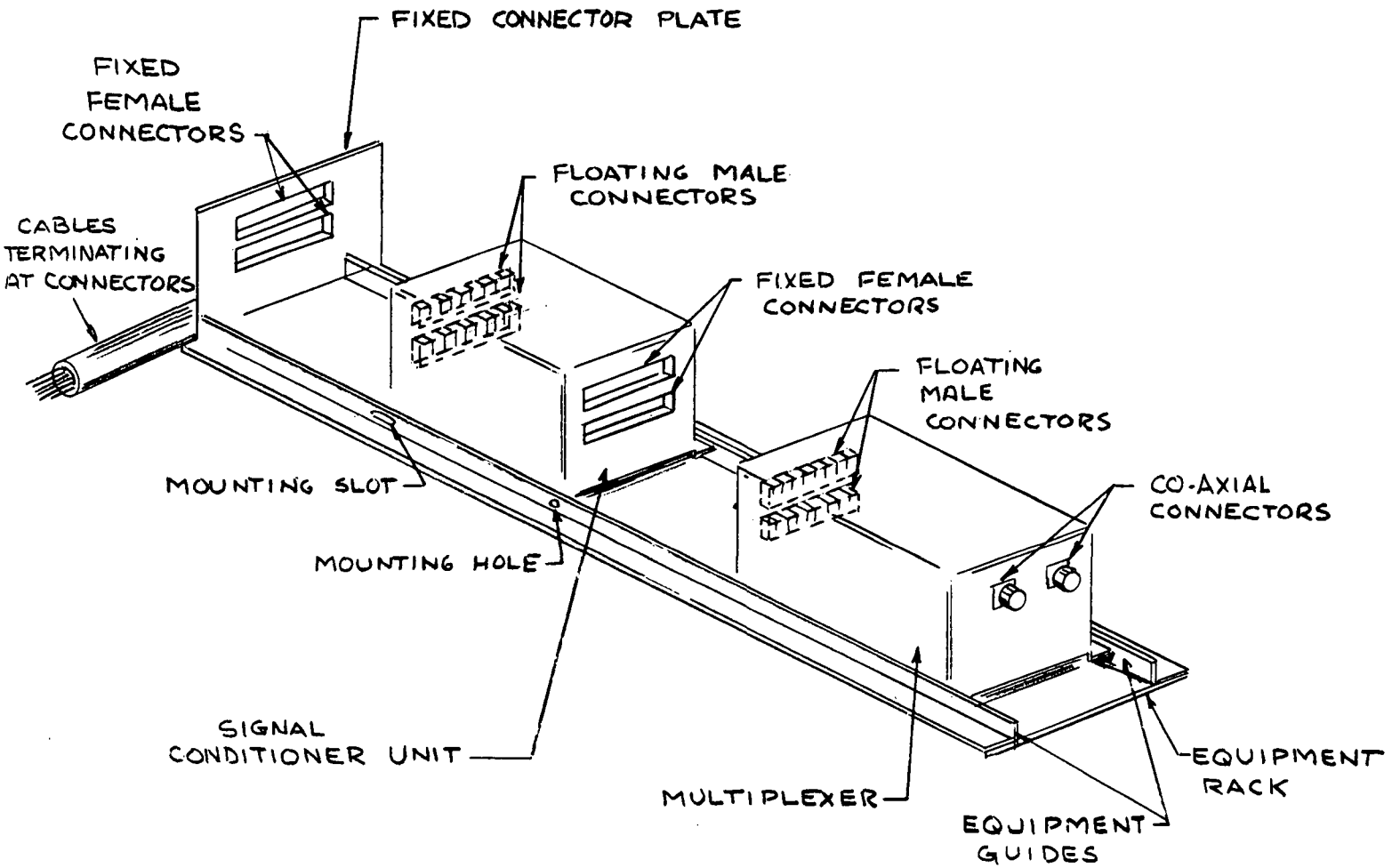


Fig. 1-11 Suggested Mounting Method for Multiplexer and Signal-Conditioning Unit

1.6.2 Technical Discussion

1.6.2.1 Strain-Gage Module

The strain-gage module provides a bridge null balance adjustable resistor and a series resistor for adjusting bridge excitation. If transducers are standardized at 2 mv/v of excitation, module wiring can be simplified by eliminating the bridge excitation resistor. Automatic null balance, which has been incorporated successfully at various test facilities in connection with fast data-handling systems, is not proposed due to added circuit complexity and weight. Excitation isolation is provided for potentiometer-type transducers by a diode in the excitation lead. These transducers can be centrally excited from a single DC supply.

Solution No. 4 in Subsection 1.4.4.1 proposed two possible locations for the bridge calibration resistor – in the strain-gage module or within the transducer itself – and discussed the relative technical merits of the two locations. Figures 1-8, 1-9, and 1-10 do not show the calibration resistor in the transducer but it is a possible location. A method of switching either manually or electrically, or both, must be provided, depending upon data-handling calibration requirements. These factors are discussed in Subsection 1.4, "Calibration."

1.6.2.2 RTB Module

The RTB module provides a standard three-wire resistance temperature bulb bridge circuit, in which the RTB is one leg of a balanced bridge, with the

effect of lead resistance cancelled out by the third wire connection to the RTB. Module components will be sized for the various temperature ranges expected on the vehicle.

Excitation can be centrally provided or individually provided, diode isolation being supplied for either case. Calibration will be accomplished by switching in a pre-cut resistor, corresponding to a standard temperature, in place of the RTB, inasmuch as the RTB ambient temperature cannot be predicted. The switching device can be contained in the module or in a central switching bank. It is proposed that the resistor and switching device be mounted in the module.

1.6.2.3 Position Module

The position module provides diode excitation as well as isolation and ranging resistors. Calibration can be accomplished by permanently shunting the position pickoff resistor with a pre-cut resistor corresponding to a standard position and switching between the position pickoff resistor and the pre-cut resistor.

1.6.2.4 Thermocouple Module

The design and operation of the thermocouple module is as follows. The voltage E_t, generated by the thermocouple of the measuring point, is added to the voltage E_c generated at the compensating resistor. A third voltage, E_j, generated by the cold junction, is subtracted from voltage E_t. The

resultant output $E_o = E_t - E_j + E_c$. The voltage E_c is developed across a temperature-sensitive resistor having a temperature coefficient matched to the type of thermocouple used. The cold junction and temperature-sensitive resistor are encapsulated in the same module. By maintaining a minimum temperature difference between these points, maximum accuracy is obtained. By proper design the voltage E_c will approach and equal E_j.

$$E_o = E_t + E_j - E_c$$

If

$$E_c = E_j$$

then

$$E_o = E_t$$

The basic circuitry is shown in Fig. 1-12. It consists of a solid-state square-wave oscillator and a zener diode rectifier circuit feeding the temperature-sensitive resistor. The unit is available from Servomechanism Inc., Los Angeles, Calif.

1.6.3 Signal-Conditioning Amplifiers

Signal-conditioning-module outputs will be supplied to stabilized DC amplifiers with outputs over the 0–5 v DC range. Preliminary specifications for these amplifiers are listed in Table 1-8. Preliminary models will be supplied by several vendors and will be subject to various radiation tests at the

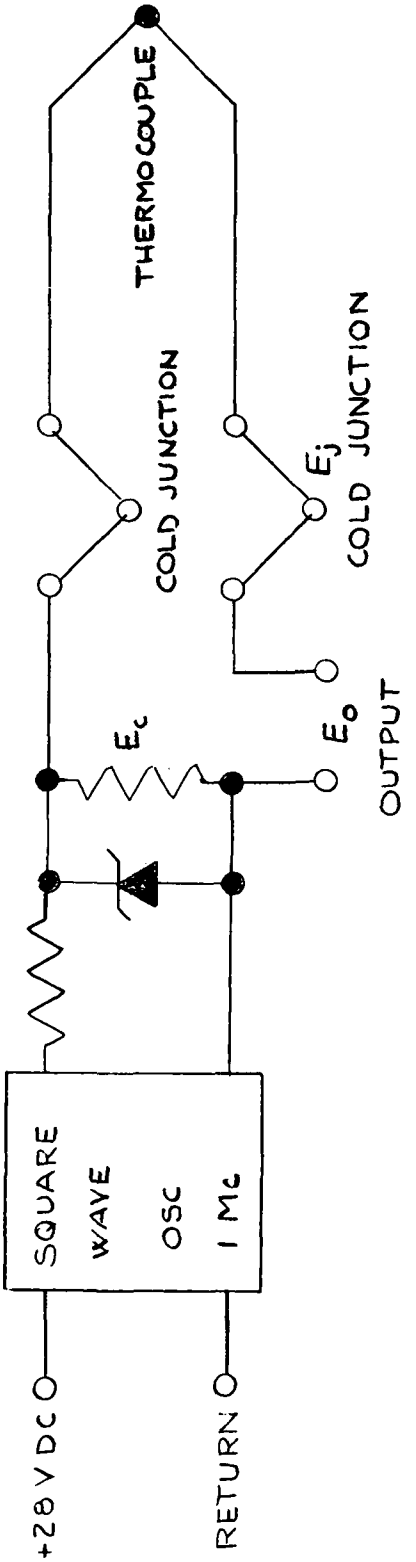


Fig. 1-12 Thermocouple Reference Circuit

Table 1-8

PRELIMINARY HARDENED HIGH-TEMPERATURE AMPLIFIER REQUIREMENTS

Input	Differential
Input voltage	± 25 mv
Output	Single-ended isolated
Gain	10 – 50 – 100 – 250 – 500 (five steps)
Gain and Zero Stability	0.5% per 8 hr
Input Impedance	100 K min.
Source Impedance	1 K max.
Full-Scale Output	+ 5 v (biased to + 2.5 v)
Temperature Zero Shift	0.003%/°F
Gain Temperature Coefficient	0.003%/°F
Common Mode Rejection	100 db at DC
Frequency Response	0 – 300 cps flat within ± 3%
Output Impedance	5 K max.
Temperature Range	-65 to +300°F
Vibration Tolerance	30 – 2,000 cps 15 g sinusoidal
Power Input	+28 v DC ± 3 v
Neutron Dose	2×10^{14} nvt without degradation
Gamma Dose	2×10^{6} Rads without degradation

Lockheed Reactor Facility in Georgia. A comparison of proposed models is presented in Table 1-9.

1.6.4 LMSC Recommendation

Vendors will be encouraged to take the steps necessary to make their amplifiers meet LMSC specifications. Marginal failure to meet the specifications will not disqualify vendors insofar as participating in the Lockheed-Georgia Company radiation testing is concerned. Results of that testing, assuming all other factors equal, will be the major factor governing selection of a signal-conditioning amplifier contractor for the RIFT Program.

Table 1-9

COMPARISON OF PROPOSED AMPLIFIER MODELS

Mfr, Model	Gain (%)	Output (v DC)	Temp. (°F)	Input Pwr (v DC/ma)	Size (in.)	Weight (oz.)
BLH 750	200 ±5% (fixed)	0–5	-50 to +250	28 ±4/90	4 x 2 x 2.5[a]	3.5[a]
Statham SA12-1	50 to 500 (variable)	0–5	-65 to +165	28 ±2.8/100	1.2 x 3.9 x 1.9	12
CEC -0100	100 to 1,000 (adjustable)	±5	0 to 275	+22, -22/70	2 x 2 x 1.3	3
Electra RHA	10 to 500 (adjustable)	0–5	-65 to 300	28 ±3/50	2.3 x 2 x 1.2	<8

Mfr, Model	Input Z (Gain/Z)	Output Z (ohm)	Gain Stability (%/hr)	Com. Mode Rejection (cps/db)	Vibration (cps/g)	Freq. Response (cps/db/gain/%)
BLH 750	NS[b]/>40K	<5.1K	±0.05/8	DC/140 400/100	2 KC/100	20KC/3/200/ 50KC/3/45/
Statham SA12-1	NS	<3.5K	NS	NS	30-2KC/35	20KC/ /NS/5
CEC -0100	NS/>10^6	<150	±1/NS	DC/100 1KC/80	2KC/50	20KC/1/NS/ 50KC/3/NS/
Electra RHA	500/50K	<2.5	0.5/8	DC/80	NS	1KC/ /NS/3 10KC/3/NS/ /

(a) LMSC estimate

(b) Not specified

Table 1-1

VEHICLE MEASUREMENT LIST

System Designation (1st letter)	Parameter (2nd letter)	Area Code (2nd number)
A = Main Propulsion System	A = Position	1 = Nose Cone
B = Secondary Propulsion System	B = Pressure	2 = Equipment Bay
C = Engine Control System	C = Temperature	3 = Tank Forward Bulk.
D = Structures	D = Flow Rate	4 = Tank Midsection
E = General	E = Strain	5 = Tank Aft Bulkhead
F = General Performance and Control Evaluation	F = Vibration	6 = Engine
G = Guidance and Control System	G = Acceleration	7 = Interstage
H = Attitude Control	H = Rate/RPM	8 = S-IC
J = Communications System	J = Sequence	9 = S-II
K = Ground-Space Command System	K = Voltage, Current, Power	
L = Destruct System	L = Acoustics	
M = Tracking Systems	M = Radiation	
N = Azusa	N = Rate (Deg/Sec)	
P = Electrical System	P = Liquid Level	
R = S-IC and S-II Stages	R = Thrust	
	S = H_2 Leak Detection	

Example - A1A-1 designator: Main propulsion system, vehicle measurement No. 1, position, nose cone. First letter = system designation; first number = vehicle measurement number; second letter = parameter; second number = area code.

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A1A-5	Propellant Valve		Position	0-100%	± 2	8 cps	Angular Pot	5 VDC	None	5K OHMS	$2x10^{12}$	$7x10^{7}$	1 MA at 5 VDC
A2A-6	Control Drum Actuator	MP	Position	0-100%	± 2	8	" "	5 VDC	"	5K OHMS	"	"	"
A3A-6	↑	↑	↑	↑	↑	↑	" "	5 VDC	"	5K OHMS	"	"	"
A4A-6							" "	5 VDC	"	5K OHMS	"	"	"
A5A-6							" "	5 VDC	"	5K OHMS	"	"	"
A6A-6							" "	5 VDC	"	5K OHMS	"	"	"
A7A-6							" "	5 VDC	"	5K OHMS	"	"	"
A8A-6							" "	5 VDC	"	5K OHMS	"	"	"
A9A-6							" "	5 VDC	"	5K OHMS	"	"	"
A10A-6							" "	5 VDC	"	5K OHMS	"	"	"
A11A-6							" "	5 VDC	"	5K OHMS	"	"	"
A12A-6	↓	↓	↓	↓	↓	↓	" "	5 VDC	"	5K OHMS	"	"	"
A13A-6	Control Drum Actuator	MP	Position	0-100%	± 2	8	" "	5 VDC	"	5K OHMS	"	"	"
A14A-6	Tank Shutoff Valve	P	Position	0-100%	± 2	2	" "	5 VDC	"	5K OHMS	"	"	"
A15A-6	Turbine Pwr. Cont.	P	Position	0-100%	± 2	8	" "	5 VDC	"	5K OHMS	"	"	"
A16A-6	Cooldown Control Valve	P	Position	0-100%	± 2	2	" "	5 VDC	"	5K OHMS	"	"	"
A17A-6	Roll Control Nozzle	P	Position	± 30°	± 2	15	" "	5 VDC	"	5K OHMS	"	"	"
A18A-6	Roll Control Nozzle	P	Position	± 30°	± 2	15	" "	5 VDC	"	5K OHMS	"	"	"
A19B-6	Pump Inlet	P	Pressure	0-40 PSIA	± 1	8	Bellows Pot	5 VDC	"	5K OHMS	$4x10^{12}$	$1x10^{8}$	"
A20B-6	Pump Inlet	P	Pressure	0-40 PSIA	± 1	8	" "	5 VDC	"	5K OHMS	"	"	"
A21B-6	Pump Outlet	MP-C	Pressure	0-1000 PSIA	± 3	8	Bourdon Tube Pot	5 VDC	"	5K OHMS	"	"	"
A22B-6	Pump Outlet	MP-C	Pressure	"	± 3	8	" " "	5 VDC	"	5K OHMS	"	"	"
A23B-6	Reflector Inlet	P	Pressure	0-800 PSIA	± 3	2	" " "	5 VDC	"	5K OHMS	$7x10^{12}$	$2x10^{8}$	"
A24B-6	Reflector Inlet	P	Pressure	"	"	2	" " "	5 VDC	"	5K OHMS	"	"	"
A25B-6	Reflector Inlet	P	Pressure	0-800 PSIA	± 3	2	" " "	5 VDC	"	5K OHMS	"	"	"
A26B-6	Core Inlet	P	Pressure	"	"	2	" " "	5 VDC	"	5K OHMS	$3x10^{13}$	$2x10^{8}$	"
A27B-6	Core Inlet	P	Pressure	"	"	2	" " "	5 VDC	"	5K OHMS	"	"	"
A28B-6	Core Inlet	P	Pressure	"	"	2	" " "	5 VDC	"	5K OHMS	"	"	"
A29B-6	Thrust Chamber - Low	MP	Pressure	0-30 PSIA	± 3	2	Bellows Pot	5 VDC	"	5K OHMS	$3x10^{3}$	$2x10^{8}$	"
A30B-6	Thrust Chamber - Low	MP	Pressure	"	"	2	" "	5 VDC	"	5K OHMS	$3x10^{13}$	$2x10^{8}$	"
A31B-6	Turbine Bleed Line	P	Pressure	0-700 PSIA	"	0.5	Bourdon Tube Pot	5 VDC	"		$2x10^{12}$	$4x10^{7}$	"
A32B-6	Turbine Drive Line	P	Pressure	"	"	0.5	" " "	5 VDC	"		"	"	"
A33B-6	Turbine Inlet Line	P	Pressure	"	"	0.5	" " "	5 VDC	"		"	"	"
A34B-6	Turbine Inlet Line	P	Pressure	"	"	0.5	" " "	5 VDC	"		"	"	"
A35B-6	Turbine Outlet Line	P	Pressure	0-60 PSIA	"	0.5	Bellows Pot	5 VDC	"		"	"	"
A36B-6	Turbine Outlet Line	P	Pressure	"	"	0.5	" "	5 VDC	"		"	"	"
A37B-6	Roll Cont. Nozzle	P	Pressure	"	± 2	8	" "	5 VDC	"		"	"	"
A38B-6	Roll Cont. Nozzle	P	Pressure	"	"	8	" "	5 VDC	"		"	"	"
A39B-6	Turbine Pump Assemb. Coolant	P	Pressure	0-700 PSIA	± 3	0.5	Bourdon Tube Pot	5 VDC	"		"	"	"
A40B-6	H_2 Gas Accumulator	MP-C	Pressure	0-700 PSIA	"	0.5	" " "	5 VDC	"		"	"	"
A41B-6	H_2 Gas Accumulator	MP-C	Pressure	"	"	0.5	" " "	5 VDC	"		"	"	"
A42B-6	H_2 Gas Accumulator	MP-C	Pressure	"	"	0.5	" " "	5 VDC	"		"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A43B-6	Coolant System	P	Pressure		± 3	0.5 cps	Bellows Pot	5 VDC	None	5K OHMS	$4x10^{12}$	$2x10^{8}$	1 MA at 5 VDC
A44B-6	Coolant System	P	Pressure		"	0.5	" "	5 VDC	"	"	"	"	"
A45B-6	Coolant System	P	Pressure		"	0.5	" "	5 VDC	"	"	"	"	"
A46B-6	Actuation Gas Inlet	P	Pressure	0-250 PSIA	"	0.5	Bourdon Tube Pot	5 VDC	"	"	$2x10^{12}$	$4x10^{7}$	"
A47B-6	Actuation Gas Inlet	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A48B-6	Actuation Gas Outlet	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A49B-6	Shield Exit	P	Pressure	0-700 "	"	0.5	" " "	5 VDC	"	"	$4x10^{12}$	$1x10^{8}$	"
A50B-6	Cont. Drum Actuation	MP	Pressure	0-250 "	"	8	" " "	5 VDC	"	"	$2x10^{12}$	$7x10^{7}$	"
A51B-6	Cont. Drum Actuation	MP	Pressure	" "	"	8	" " "	5 VDC	"	"	"	"	"
A52B-6	Regulator - Out	P	Pressure	0-300 "	"	0.5	" " "	5 VDC	"	"	"	"	"
A53B-6	Regulator - Out	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A54B-6	Regulator - Out	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A55B-6	Regulator - Out	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A56B-6	Regulator - Out	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"	"	"	"
A57B-6	Regulator - In	P	Pressure	0-700 "	"	0.5	" " "	5 VDC	"	"			"
A58B-6	Regulator - In	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"			"
A59B-6	Regulator - In	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"			"
A60B-6	Regulator - In	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"			"
A61B-6	Regulator - In	P	Pressure	" "	"	0.5	" " "	5 VDC	"	"			"
A62C-6	Pump Inlet	P	Temperature	-430 to -375°F	"	0.5	Plat.Res.Therm.	5 VDC Sig.Cond	Needed	100 OHMS			13 MA at 28 VDC
A63C-6	Pump Inlet	P	Temperature	"	"	0.5	" " "	"	"	"			"
A64C-6	Pump Outlet	MP	Temperature	"	"	0.5	" " "	"	"	"			"
A65C-6	Pump Outlet	MP	Temperature	"	"	0.5	" " "	"	"	"	$2x10^{12}$	$7x10^{7}$	"
A66C-6	Reflector Inlet	P	Temperature	-430 to -340° F	"	0.5	" " "	"	"	"	$1x10^{13}$	$2x10^{8}$	"
A67C-6	Reflector Inlet	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A68C-6	Reflector Inlet	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A69C-6	Reflector Structure	P	Temperature		"	0.5	" " "	"	"	"	↕	↕	"
A70C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A71C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A72C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A73C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A74C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A75C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A76C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A77C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A78C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A79C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A80C-6	Reflector Structure	P	Temperature	"	"	0.5	" " "	"	"	"	↕	↕	"
A81C-6	Core Modules	P	Temperature	0-5000°F	"	0.5	Tungsten-Tungsten 26% Rhenium T/C	42 MV	"	"			None
A82C-6	Core Modules	P	Temperature	"	"	0.5	" " "		"	"			"
A83C-6	Core Modules	P	Temperature	"	"	0.5	" " "	"	"	"			"
A84C-6	Core Modules	P	Temperature	"	"	0.5	" " "	"	"	"	$1x10^{13}$	$2x10^{8}$	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A85C-6	Core Modules	P	Temperature	0-5000°F	± 3	0.5 cps	Tungsten-Tungsten 26% Rhenium T/C	42 MV	Needed	100 OHMS	$1x10^{13}$	$2x10^{8}$	None
A86C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A87C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A88C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A89C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A90C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A91C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A92C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A93C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A94C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A95C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A96C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A97C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A98C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A99C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A100C-6	Core Modules	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A101C-6	Turbine Nozzle Support	P	Temperature	0-1000°F	"	0.5	Chromel-Constantan T/C	41 MV	"	"	"	"	"
A102C-6	Turbine Nozzle Support	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A103C-6	Turbine Nozzle Support	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A104C-6	Turbine Nozzle Support	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A105C-6	Core Outlet	P	Temperature	0-5000°F	"	0.5	Tungsten-Tungsten 26% Rhenium T/C	42 MV	"	"	"	"	"
A106C-6	Core Outlet	P	Temperature	"	"	0.5		"	"	"	"	"	"
A107C-6	Core Outlet	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A108C-6	Core Outlet	P	Temperature	"	"	0.5	" "	"	"	"	$1x10^{13}$	$2x10^{8}$	"
A109C-6	Turbine Bleed Line	P	Temperature	-430 to -150°F	"	0.5	Plat.Res.Therm.	5 VDC Sig.Cond.	"	"	$2x10^{12}$	$7x10^{7}$	13 MA at 28 VDC
A110C-6	Turbine Drive Line	P	Temperature	-430 to +800°F	"	0.5	" "	"	"	"	"	"	"
A111C-6	Turbine Inlet Line	MP	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A112C-6	Turbine Inlet Line	MP	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A113C-6	Turbine Outlet Line	P	Temperature	-430 to +500°F	"	0.5	" "	"	"	"	"	"	"
A114C-6	Roll Cont. Nozzles	P	Temperature	"	"	0.5	" "	"	"	"	$1x10^{13}$	$2x10^{8}$	"
A115C-6	Roll Cont. Nozzles	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A116C-6	Turb.Pump.Assemb.Coolant	P	Temperature		"	0.5					$2x10^{12}$	$7x10^{7}$	
A117C-6	H_2 Gas Accumulator	P	Temperature	-210 to +140°F	"	2 cps	" "	5 VDC Sig.Cond.	"	"	$2x10^{12}$	$2x10^{7}$	13 MA at 28 VDC
A118C-6	H_2 Gas Accumulator	P	Temperature	"	"	2 cps	" "	"	"	"	"	"	"
A119C-6	Coolant System	P	Temperature		"	0.5					$3x10^{13}$	$4x10^{8}$	
A120C-6	Coolant System	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A121C-6	Coolant System	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A122C-6	Coolant System	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A123C-6	Act.Cooling Gas Inlet	P	Temperature	-430 to +1100°F	"	0.5	" "	"	"	"	$2x10^{12}$	$2x10^{7}$	"
A124C-6	Reflector Graphite Outer	P	Temperature	0-5000°F	"	0.5	Tungsten-Tungsten 26% Rhenium T/C	42 MV	"	"	$5x10^{13}$	$4x10^{8}$	None
A125C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"
A126C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	" "	"	"	"	"	"	"

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VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASURMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A127C-6	Reflector Graphite Inner	P	Temperature	0-5000°F	± 3	0.5 cps	Tungsten-Tungsten 26% Rhenium T/C	42 MV	Needed	100 OHMS	$5x10^{13}$	$4x10^{18}$	None
A128C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A129C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A130C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A131C-6	Reflector Graphite Inner	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A132C-6	Control Drum Accuator	P	Temperature		"	0.5							
A133C-6	Control Drum Accuator	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A134C-6	Control Drum Accuator	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A135C-6	Control Drum Accuator	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A136C-6	Shield & Support	P	Temperature		"	0.5							
A137C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A138C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A139C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A140C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A141C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A142C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A143C-6	Shield & Support	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A144C-6	Exhaust Nozzle to Reactor Seal	P	Temperature		"	0.5							
A145C-6	Exh.Nozzle to Reactor Seal	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A146C-6	LH_2 - Nozzle Inlet	P	Temperature	-430 to -375°	"	0.5	Plat.Res.Therm.	5 VDC	Sig.Cond.	"	"	"	13 MA at 28 VDC
A147C-6	LH_2 - Nozzle Inlet	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A148C-6	LH_2 - Nozzle Inlet	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A149C-6	Top Support Plate	P	Temperature	-430 to +500°F	"	0.5	"	"	"	"	"	"	"
A150C-6	Top Support Plate	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A151C-6	Top Support Plate	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A152C-6	Top Support Plate	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A153C-6	Top Support Plate	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A154C-6	Core Support Barrel	P	Temperature		"	0.5							
A155C-6	Core Support Barrel	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A156C-6	Core Support Barrel	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A157C-6	Core Support Barrel	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A158C-6	Control Drum	P	Temperature		"	0.5							
A159C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A160C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A161C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A162C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A163C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A164C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A165C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A166C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A167C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A168C-6	Control Drum	P	Temperature	"	"	0.5	"	"	"	"	$5x10^{13}$	$4x10^{18}$	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A169C-6	Control Drum	P	Temperature		± 3	0.5 cps					$5x10^{13}$	$4x10^{8}$	
A170C-6	Pressure Shell	P	Temperature	-430° to 2000°F	3	0.5	Plat.Res.Therm.	5 VDC Sig.Cond.	Needed	100 OHMS	"	"	13 MA at 28 VDC
A171C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A172C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A173C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A174C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A175C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A176C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A177C-6	Pressure Shell	P	Temperature	"	3	0.5	"	"	"	"	"	"	"
A178C-6	Nozzle	P	Temperature	0 to 2000°F	3	0.5	"	"	"	"	"	"	"
A179C-6	Nozzle	P	Temperature	"	"	0.5	"	"	"	"	"	"	"
A180D-6	Main Propellant	P	Flowrate	0-100 lb/s	2	15	Mass flowmeter to be developed	"	"	250 OHMS	"	"	750 MA at 28 VDC
A181D-6	Tank Pressurizing Line	P	Flowrate	0-2 lb/s	2	0.5	"	"	"	"	"	"	"
A182D-6	Coolant Lunar Graphite Refl.	P	Flowrate		2	0.5	"	"	"	"	"	"	"
A183D-6	Coolant Lunar Grph.Refl.	P	Flowrate		2	0.5	"	"	"	"	"	"	"
A184D-6	Cont.Drum Act Drive fluid	P	Flowrate	0-0.4 lb/s	2	0.5	"	"	"	"	"	"	"
A185D-6	Upper Flange Coolant	P	Flowrate	0-2 lb/s	2	0.5	"	"	"	"	"	"	"
A186D-6	Turbine Bleed Line	P	Flowrate	0-4 lb/s	2	0.5	"	"	"	"	"	"	"
A187E-6	Pressure Vessel	P	Strain	0-.01 in/in	3	0.5	Bonded strain gage	"	"	1000 OHMS	"	"	20 MA at 10 VDC
A188E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A189E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A190E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A191E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A192E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A193E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A194E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A195E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A196E-6	Pressure Vessel	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A197E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A198E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A199E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A200E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A201E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A202E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A203E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A204E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A205E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A206E-6	Nozzle	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A207E-6	Thrust Structure	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A208E-6	Thrust Structure	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A209E-6	Thrust Structure	P	Strain	"	3	0.5	"	"	"	"	"	"	"
A210E-6	Thrust Structure	P	Strain	"	3	0.5	"	"	"	"	"	"	"

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VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRAONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A211E-6	Thrust Structure	P	Strain	0-.01 in/in	±3	0.5 cps	Bonded strain gage	5 VDC	Needed	1000 OHMS	$5x10^{13}$	$4x10^{8}$	20 MA at 10 VDC
A212E-6	Thrust Structure	P	Strain	"	"	"	"	Sig.Cond.	"	"	"	"	"
A213E-6	Thrust Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A214E-6	Thrust Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A215E-6	Thrust Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A216E-6	Thrust Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A217E-6	Reactor Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A218E-6	Reactor Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A219E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A220E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A221E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A222E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A223E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A224E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A225E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A226E-6	" "	P	Strain	"	"	"	"	"	"	"	"	"	"
A227E-6	Inter. Thrust Struct.	P	Strain	"	"	"	"	"	"	"	"	"	"
A228E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A229E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A230E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A231E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A232E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A233E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A234E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A235E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A236E-6	" " "	P	Strain	"	"	"	"	"	"	"	"	"	"
A237E-6	Turbo Pump Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A238E-6	Turbo Pump Structure	P	Strain	"	"	"	"	"	"	"	"	"	"
A239F-6	Turbo Pump	P	Vibration	± 100 g	3	2000	Piezo electric vib. pickup	5 VDC with amp	"	2000 OHMS	"	"	50 MA at 28 VDC
A240F-6	Turbo Pump	P	Vibration	"	"	"	"	"	"	"	"	"	"
A241F-6	Turbo Pump	P	Vibration	"	"	"	"	"	"	"	"	"	"
A242G-6	Main Thrust Structure	P	Acceleration	± 50 g	"	250	Gas damped unbonded strain gage	"	"	"	"	"	"
A243G-6	Main Thrust Structure	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A244G-6	Main Thrust Structure	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A245G-6	Roll Control Nozzle	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A246G-6	Roll Control Nozzle	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A247F-6	Reactor Core-Dummy Eng.	P	Vibration	± 100 g	"	2000	Piezo Electric vib. pickup	"	"	"	"	"	"
A248F-6	Reactor Core-Dummy Eng.	P	Vibration	"	"	"	"	"	"	"	"	"	"
A249F-6	Reactor Core-Dummy Eng.	P	Vibration	"	"	"	"	"	"	"	"	"	"
A250F-6	Reactor Core-Dummy Eng.	P	Vibration	"	"	"	"	"	"	"	"	"	"
A251G-6	Nozzle	P	Acceleration	± 50 g	3	250	Gas damped unbonded strain gage	"	"	"	$5x10^{13}$	$4x10^{8}$	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
A252G-6	Nozzle	P	Acceleration	± 50 g	±3	250 cps	Gas damped unbonded strain gage	5 VDC w/amp.	Needed	2000 OHMs	$5x10^{13}$	$1x10^{8}$	50 MA at 28 VDC
A253G-6	Nozzle	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A254G-6	Actuator	P	Acceleration	± 100 g	"	"	"	"	"	"	"	"	"
A255G-6	"	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A256G-6	"	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A257G-6	"	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A258G-6	Reactor Pressure Shell	P	Acceleration	± 100 g	3	250	"	"	"	"	"	"	"
A259G-6	" " "	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A260G-6	" " "	P	Acceleration	"	"	"	"	"	"	"	"	"	"
A261H-6	Turbine RPM	P	Rate	0-23 Krpm	1	0.5	magnetic pickup & converter	"	"	"	"	"	"
A262I-6	Propellant Valve	P	Sequence	Open Closed	3	15	Switch	5 VDC	None	10 OHMS	"	"	Negligible
A263J-6	Control Drum Lock	P	Sequence	Locked-Unlocked	3	0.5	"	"	"	"	$5x10^{13}$	$1x10^{8}$	"
B264B-7	Interstage Lunar Fwd	P	Pressure	0-15 psia	3	2	bellows pot type	"	"	"	$5x10^{11}$	$5x10^{6}$	"
B265B-7	" " "	P	"	"	"	"	"	"	"	"		"	"
B266B-7	" " "	P	"	"	"	50	unbonded strain gage	5 VDC w/amp	Needed	2000 OHMS		"	50 MA at 28 VDC
B267B-7	" " "	P	"	"	"	"	"	"	"	"		"	"
B268C-6	Engine Thrust Ribs	P	Temperature	-300° +500°F	"	0.5	Plat.Res.Therm	"	"	"	$1x10^{12}$	$1x10^{7}$	13 MA at 28 VDC
B269C-6	" " "	P	"	"	"	"	"	"	"	"	"	"	"
B270D-5	Main Tank to Overboard	P	Flow rate	0-0.1 lb/s	3	0.5	Mass type flow meter to be developed	"	"	"	$2x10^{11}$	$2x10^{6}$	50 MA at 28 VDC
B271D-5	Accumulator to Tank	P	"	0-0.5 lb/s	3	0.5	"	"	"	"	"	"	"
B272D-5	Accum. to Vector Cont.	P	"	"	"	"	"	"	"	"	"	"	"
C273K-2	Throttle Valve Position Com.	MP	Voltage		2	0.5	---------- VOLTAGE OUTPUT TO BE SUPPLIED BY ENGINE MANUFACTURER ----------						
C274K-2	Turbine Bypass Valve Com	MP	"		"	"		"	"	"	"		
C275K-2	Tachometer Ref	MP	"		"	"		"	"	"	"		
C276K-2	Control Drum Posit.Com.	MP	"		"	"		"	"	"	"		
C277K-2	" " " "	MP	"		"	"		"	"	"	"		
C278K-2	" " " "	MP	"		"	"		"	"	"	"		
C279K-2	" " " "	MP	"		"	"		"	"	"	"		
C280K-2	" " " "	MP	"		"	"		"	"	"	"		
C281K-2	" " " "	MP	"		"	"		"	"	"	"		
C282K-2	" " " "	MP	"		"	"		"	"	"	"		
C283K-2	" " " "	MP	"		"	"		"	"	"	"		
C284K-2	" " " "	MP	"		"	"		"	"	"	"		
C285K-2	" " " "	MP	"		"	"		"	"	"	"		
C286K-2	" " " "	MP	"		"	"		"	"	"	"		
C287K-2	" " " "	MP	"		"	"		"	"	"	"		
C288K-2	Control Drum Pot Ref.	MP	"		"	"		"	"	"	"		
C289K-2	" " " "	MP	"		"	"		"	"	"	"		
C290K-2	" " " "	MP	"		"	"		"	"	"	"		
C291K-2	" " " "	MP	"		"	"		"	"	"	"		
C292K-2	" " " "	MP	"		"	"		"	"	"	"		
C293K-2	" " " "	MP	"		"	"		"	"	"	"		

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VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
C294K-2	Cont. Drum Pot Ref.	MP	Voltage		±2	0.5 cps	---------- VOLTAGE OUTPUT TO BE SUPPLIED BY ENGINE MANUFACTURER ----------				$2x10^{11}$	$2x10^{6}$	
C295K-2	" " " "	MP	"		2	"		"	"	"	"	"	
C296K-2	" " " "	MP	"		"	"		"	"	"	"	"	
C297K-2	" " " "	MP	"		"	"		"	"	"	"	"	
C298K-2	" " " "	MP	"		"	"		"	"	"	"	"	
C299K-2	" " " "	MP	"		"	"		"	"	"	"	"	
C300K-2	Cont Drum Scram	MP	"		"	"		"	"	"	"	"	
C301K-2	" " "	MP	"		"	"		"	"	"	"	"	
C302K-2	" " "	MP	"		"	"		"	"	"	"	"	
C303K-2	" " "	MP	"		"	"		"	"	"	"	"	
C304K-2	" " "	MP	"		"	"		"	"	"	"	"	
C305K-2	" " "	MP	"		"	"		"	"	"	"	"	
C306K-2	" " "	MP	"		"	"		"	"	"	"	"	
C307K-2	" " "	MP	"		"	"		"	"	"	"	"	
C308K-2	" " "	MP	"		"	"		"	"	"	"	"	
C309K-2	" " "	MP	"		"	"		"	"	"	"	"	
C310K-2	" " "	MP	"		"	"		"	"	"	"	"	
C311K-2	" " "	MP	"		"	"		"	"	"	"	"	
C312K-2	Pneumatic Supply	MP	"		"	"		"	"	"	"	"	
C313K-2	Ion Chamber	MP-C	"	0-800 V	"	"		"	"	"	"	"	
C314K-2	" "	MP-C	"	"	"	"		"	"	"	"	"	
C315K-2	" "	MP-C	"	"	"	"		"	"	"	"	"	
C316K-2	Propellant Valve Com.	MP	"		"	"		"	"	"	"	"	
C317K-2	Prop. Bypass Valve Com.	MP	"		"	"		"	"	"	"	"	
C318J-6	Control Drum Limit SW	MP	Sequence	Open-Closed	3	15	TRANSDUCER OUTPUT, SEPARATE FROM CONTROL DEVICE, TO BE SUPPLIED BY ENGINE MFG.						
C319J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C320J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C321J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C322J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C323J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C324J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C325J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C326J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C327J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C328J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C329J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C330J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C331J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C332J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C333J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C334J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	
C335J-6	" " " "	MP	"	"	"	"	"	"	"	"	"	"	

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
C336J-6	Control Drum Limit SW	MP	Sequence	Open-Closed	±3	15 cps	TRANSDUCER OUTPUT, SEPARATE FROM CONTROL DEVICE, TO BE SUPPLIED BY ENGINE MFG.						
C337J-6	" " " "	MP	"	"	"	"	"	"	"	"	"		
C338J-6	" " " "	MP	"	"	"	"	"	"	"	"	"		
C339J-6	" " " "	MP	"	"	"	"	"	"	"	"	"		
C340J-6	" " " "	MP	"	"	"	"	"	"	"	"	"		
C341J-6	" " " "	MP	"	"	"	"	"	"	"	"	"		
C342A-6	Control Drum	MP-C	Position	0-180°	2	8	"	"	"	"	"		
C343A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C344A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C345A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C346A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C347A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C348A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C349A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C350A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C351A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C352A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C353A-6	" "	MP-C	"	"	"	"	"	"	"	"	"		
C354A-6	Turbine Bypass Valve	MP	"	0-100%	2	8	"	"	"	"	"		
C355A-6	Turb Throttle Valve	MP	"	"	"	"	"	"	"	"	"		
C356A-6	Propellant Bypass Valve	MP	"	"	"	"	"	"	"	"	"		
C357B-6	Chamber	MP-2C	Pressure	0-650 psia	2	50	"	"	"	"	"		
C358B-6	"	MP-2C	"	"	"	"	"	"	"	"	"		
C359B-6	"	MP-2C	"	"	"	"	"	"	"	"	"		
C360C-6	"	MP-C	Temperature	0-4000°F	2	2	"	"	"	"	"		
C361C-6	"	MP-C	"	"	"	"	"	"	"	"	"		
C362C-6	"	MP-C	"	"	"	"	"	"	"	"	"		
C363C-6	Core Inlet	MP	"	-430 to -250°F	2	0.5	"	"	"	"	"		
C364C-6	" "	MP	"	"	"	"	"	"	"	"	"		
C365C-6	" "	MP	"	"	"	"	"	"	"	"	"		
C366H-6	Turbine RPM	MP	Rate	0-23 K	1	2	"	"	"	"	"		
D367E-1	Nose Cone	P	Strain	0-.01 in/in	3	0.5	Bonded strain gage	5 VDC w/smp	Needed	1000 OHMS	2×10^{11}	2×10^{6}	20 MA at 10 VDC
D368E-1	" "	P	"	"	"	"	"	"	"	"	"	"	"
D369E-1	" "	P	"	"	"	"	"	"	"	"	"	"	"
D370E-1	" "	P	"	"	"	"	"	"	"	"	"	"	"
D371E-1	" "	P	"	"	"	"	"	"	"	"	"	"	"
D372E-1	" "	P	"	"	"	"	"	"	"	"	"	"	"
D373E-3	Tank Fwd Skirt	P	"	"	"	"	"	"	"	"	"	"	"
D374E-3	" " "	P	"	"	"	"	"	"	"	"	"	"	"
D375E-3	" " "	P	"	"	"	"	"	"	"	"	"	"	"
D376E-3	" " "	P	"	"	"	"	"	"	"	"	"	"	"
D377E-3	" " "	P	"	"	"	"	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D378E-3	Tank Fwd Skirt	P	Strain	0-.01 in/in	3	0.5	Bonded Strain Gage	5VDC with Amp	Needed	1000 Ohms	$2x10^{11}$	$2x10^{6}$	20 MA at 10VDC
D379E-3													
D380E-3													
D381E-3													
D382E-3													
D383E-3													
D384E-3													
D385E-3													
D386E-3													
D387E-3													
D388E-3													
D389E-3													
D390E-3													
D391E-3													
D392E-3	Tank Fwd Skirt												
D393E-3	Tank Fwd Dome												
D394E-3													
D395E-3													
D396E-3													
D397E-3													
D398E-3													
D399E-3													
D400E-3													
D401E-3													
D402E-3													
D403E-3													
D404E-3	Tank Fwd Dome												
D405E-4	Tank Baffle												
D406E-4													
D407E-4													
D408E-4													
D409E-4													
D410E-4													
D411E-4													
D412E-4													
D413E-4													
D414E-4													
D415E-4													
D416E-4													
D417E-4													
D418E-4													
D419E-4	Tank Baffle	P	Strain	0-.01 in/in	3	0.5	Bonded Strain Gage	5VDC with Amp	Needed	1000 Ohms	$2x10^{11}$	$2x10^{6}$	20 MA at 10VDC

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D420E-4	Tank Baffle	P	Strain	0-.01 in/in	3	0.5	Bonded Strain Gage	5VDC with Amp	Needed	1000 Ohms	$2x10^{11}$	$2x10^{6}$	20 MA at 10VDC
D421E-4													
D422E-4													
D423E-4													
D424E-4													
D425E-4													
D426E-4													
D427E-4													
D428E-4													
D429E-4													
D430E-4													
D431E-4													
D432E-4													
D433E-4													
D434E-4													
D435E-4		P											
D436E-4	Tank Baffle	P											
D437E-5	Tank Aft Skirt	S											
D438E-5													
D439E-5													
D440E-5													
D441E-5													
D442E-5													
D443E-5													
D444E-5	Tank Aft Skirt												
D445E-7	Interstage Fwd												
D446E-7													
D447E-7													
D448E-7													
D449E-7													
D450E-7													
D451E-7													
D452E-7	Interstage Fwd										$2x10^{11}$	$2x10^{6}$	
D453E-7	Interstage Aft										$1x10^{12}$	$2x10^{7}$	
D454E-7													
D455E-7													
D456E-7													
D457E-7													
D458E-7													
D459E-7													
D460E-7	Interstage Aft	S									$1x10^{12}$	$2x10^{7}$	
D461E-5	Actuator Support	P	Strain	0-.01 in/in	3	0.5	Bonded Strain Gage	5VDC with Amp	Needed	1000 Ohms	$2x10^{12}$	$2x10^{7}$	20 MA at 10VDC

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D462E-5	Actuator Support	P	Strain	0-.01 in/in	3	0.5	Bonded Strain Gage	5VDC with Amp	Needed	1000 Ohms	$2x10^{12}$	$2x10^{7}$	20 MA at 10VDC
D463E-5											$2x10^{12}$	$2x10^{7}$	
D464E-5	Actuator Support										$2x10^{12}$	$2x10^{7}$	
D465E-5	Tank Aft										$5x10^{11}$	$1x10^{7}$	
D466E-5													
D467E-5													
D468E-5													
D469E-5													
D470E-5													
D471E-5													
D472E-5													
D473E-5													
D474E-5													
D475E-5													
D476E-5													
D477E-5													
D478E-5													
D479E-5													
D480E-5													
D481E-5													
D482E-5													
D483E-5													
D484E-5													
D485E-5													
D486E-5													
D487E-5													
D488E-5													
D489E-5													
D490E-5													
D491E-5													
D492E-5													
D493E-5													
D494E-5													
D495E-5													
D496E-5													
D497E-5													
D498E-5													
D499E-5			Strain	0-.01 in/in	3	0.5							
D500E-5	Tank Aft		Strain	0-.01 in/in	3	0.5							
D501G-2	Equipment Bay		Acceleration	±50 g	3	250	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$5x10^{11}$ $2x10^{11}$	$1x10^{7}$ $2x10^{6}$	50 MA at 28VDC
D502G-2	Equipment Bay		Acceleration	±50 g	3	250					$2x10^{11}$	$2x10^{6}$	
D503G-2	Equipment Bay	P	Acceleration	±50 g	3	250					$2x10^{11}$	$2x10^{6}$	

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D504G-3	Tank Fwd Dome	P	Acceleration	±50 g	3	250	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$2x10^{11}$	$2x10^{6}$	50 MA at 28VDC
D505G-3											$2x10^{11}$	$2x10^{6}$	
D506G-3											$2x10^{11}$	$2x10^{6}$	
D507G-3											$2x10^{11}$	$2x10^{6}$	
D508G-3											$2x10^{11}$	$2x10^{6}$	
D509G-3	Tank Fwd Dome										$2x10^{11}$	$2x10^{6}$	
D510G-5	Tank Aft										$1x10^{12}$	$1x10^{7}$	
D511G-5	Tank Aft										$1x10^{12}$	$1x10^{7}$	
D512G-5	Tank Aft										$1x10^{12}$	$1x10^{7}$	
D513G-5	Tank Thrust Point										$1x10^{12}$	$1x10^{7}$	
D514G-5	Tank Thrust Point										$1x10^{12}$	$1x10^{7}$	
D515G-5	Tank Thrust Point										$1x10^{12}$	$1x10^{7}$	
D516G-5	Main Thrust Strut										$1x10^{12}$	$1x10^{7}$	
D517G-5	Main Thrust Strut										$1x10^{12}$	$1x10^{7}$	
D518G-5	Main Thrust Strut	P									$1x10^{12}$	$1x10^{7}$	
D519G-7	Interstage Aft	S									$1x10^{12}$	$2x10^{7}$	
D520G-7	Interstage Aft										$1x10^{12}$	$2x10^{7}$	
D521G-7	Interstage Aft		Acceleration	±50 g		250	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$1x10^{12}$	$2x10^{7}$	50 MA at 28VDC
D522B-1	Nose Cone External		Pressure	0-20 psia		0.5	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
D523B-1													
D524B-1													
D525B-1													
D526B-1													
D527B-1													
D528B-1													
D529B-1													
D530B-1													
D531B-1													
D532B-1													
D533B-1													
D534B-1													
D535B-1													
D536B-1													
D537B-1													
D538B-1													
D539B-1													
D540B-1													
D541B-1	Nose Cone External	S		0-20 psia									
D542B-2	Equipment Bay	P		0-15 psia									
D543B-4	Tank External	P		0-20 psia									
D544B-4	Tank External	P											
D545B-4	Tank External	P	Pressure		3	0.5					$2x10^{11}$	$2x10^{6}$	

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D546B-4	Tank External	P	Pressure	0-20 psia	3	0.5	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
D547B-3	Tank Skirt External	S		0-20 psia							$2x10^{11}$	$2x10^{6}$	
D548B-3	Tank Skirt External	S									$2x10^{11}$	$2x10^{6}$	
D549B-3	Tank Skirt External	S									$2x10^{11}$	$2x10^{6}$	
D550B-3	Tank Skirt External	S					Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
D551B-3	Tank Fwd Dome Internal	P-C		0-40 psia			Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$2x10^{11}$	$2x10^{6}$	50 MA at 28VDC
D552B-3	Tank Fwd Internal	P									$2x10^{11}$	$2x10^{6}$	
D553B-3	Tank Fwd Internal	P									$2x10^{11}$	$2x10^{6}$	
D554B-3	Tank Fwd Internal	P									$2x10^{11}$	$2x10^{6}$	
D555B-3	Tank Fwd Internal	P									$2x10^{11}$	$2x10^{6}$	
D556B-5	Tank Aft Internal	P									$1x10^{12}$	$1x10^{7}$	
D557B-5	Tank Aft Internal	P		0-40 psia			Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$1x10^{12}$	$1x10^{7}$	50 MA at 28VDC
D558B-5	Tank Aft Skirt Internal	S		0-20 psia			Bellows-Pot	5VDC	None	5000 Ohms	$5x10^{11}$	$5x10^{6}$	1 MA at 5VDC
D559B-5	Tank Aft Skirt Internal	S									$5x10^{11}$	$5x10^{6}$	
D560B-5	Tank Aft Skirt Internal	S									$5x10^{11}$	$5x10^{6}$	
D561B-5	Tank Aft Skirt Internal	S									$5x10^{11}$	$5x10^{6}$	
D562B-5	Tank Aft Skirt External	S									$5x10^{11}$	$5x10^{6}$	
D563B-5	Tank Aft Skirt External	S									$5x10^{11}$	$5x10^{6}$	
D564B-5	Tank Aft Skirt External	S									$5x10^{11}$	$5x10^{6}$	
D565B-5	Tank Aft Skirt External	S		0-20 psia			Bellows-Pot	5VDC	None	5000 Ohms	$5x10^{11}$	$5x10^{6}$	1 MA at 5VDC
D566B-4	Tank Internal	P		0-40 psia			Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$5x10^{11}$	$5x10^{6}$	50 MA at 28VDC
D567B-4	Tank Internal	P									$5x10^{11}$	$5x10^{6}$	
D568B-5	Tank Internal Aft End	P									$1x10^{12}$	$1x10^{7}$	
D569B-5	Tank Internal Aft End	P									$1x10^{12}$	$1x10^{7}$	
D570B-5	Tank Internal Aft End	P									$1x10^{12}$	$1x10^{7}$	
D571B-5	Tank Internal Aft End	P		0-40 psia							$1x10^{12}$	$1x10^{7}$	
D572B-7	Interstage Aft Internal	S		0-15 psia			Bellows-Pot	5VDC	None	5000 Ohms	$1x10^{12}$	$2x10^{7}$	1 MA at 5VDC
D573B-7	Interstage Aft Internal	S		0-15 psia							$1x10^{12}$	$2x10^{7}$	
D574B-7	Interstage Aft Internal	S		0-15 psia							$1x10^{12}$	$2x10^{7}$	
D575B-7	Interstage Aft Internal	S	Pressure	0-15 psia	3						$1x10^{12}$	$2x10^{7}$	
D576C-1	Nose Cone Tip		Temperature	60-5000 F	1		Plat. Res. Therm.	5VDC with Amp	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	13 MA at 28VDC
D577C-1	Nose Cone External				3		Chromel-Constantan T/C	18 MV	Needed	100 Ohms			None
D578C-1													
D579C-1													
D580C-1													
D581C-1													
D582C-1													
D583C-1													
D584C-1													
D585C-1													
D586C-1													
D587C-1	Nose Cone External	S	Temperature	60-5000 F	3	0.5					$2x10^{11}$	$2x10^{6}$	

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D588C-1	Nose Cone Ext	S	Temperature	60-500°F	3	0.5	Chromel Constantan T/C	18 MV	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	None
D589C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D590C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D591C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D592C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D593C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D594C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D595C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D596C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D597C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D598C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D599C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D600C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D601C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D602C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D603C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D604C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D605C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D606C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D607C-1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D608C-1	Nose Cone Ext	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D609C-1	Nose Cone Int	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D610C-1	Nose Cone Int	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D611C-1	Nose Cone Int	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D612C-1	Nose Cone Int	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D613C-3	Tank Fwd Skirt Outer	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D614C-3	Tank Fwd Skirt Outer	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D615C-3	Tank Fwd Skirt Outer	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D616C-3	Tank Fwd Skirt Outer	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D617C-3	Tank Fwd Skirt Inner	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D618C-3	Tank Fwd Skirt Inner	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D619C-3	Tank Fwd Skirt Inner	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D620C-3	Tank Fwd Skirt Inner	S		60-500°F									
D621C-3	Tank Fwd Dome Inside Wall	P		-440° to 0°F			Plat, Res. Therm.	5VDC with Amp	Needed	100 Ohms			13 MA at 28VDC
D622C-3	Tank Fwd Dome Inside Wall	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D623C-3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D624C-3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D625C-3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D626C-3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D627C-3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
D628C-3	Tank Fwd Dome Inside Wall	P		-440° to 0°F									
D629C-4	Tank Fwd Skin Surface	P	Temperature	0 to 500°F	3	0.5	Chromel Constantan T/C	18 MV	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	None

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D630C-4	Tank Fwd Skin Surface	P	Temperature	0° to 500°F	±3	0.5cps	Chromel-Constanton T/C	18 MV	Needed	100 OHMS	2x10"	2x10^6	None
D631C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D632C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D633C-3	Tank Fwd Inside Insul.	P	Temperature	-440° to 0°F	3	0.5	Plat. Res. Therm.	5 VDC with amp.	"	"	"	"	13 MA at 28 VDC
D634C-3	"	P	"	"	3	0.5							
D635C-4	Tank Fwd Skin Inside	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D636C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D637C-4	Tank Fwd Skin Surf.	P	Temperature	0° to 500°F	3	0.5	Chromel-Constanton T/C	18 MV	"	"	"	"	None
D638C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D639C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D640C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D641C-3	Tank Fwd Inside Insu.	P	Temperature	-440° to 0°F	3	0.5	Plat. Res. Therm.	5 VDC with amp.	"	"	"	"	13 MA at 28 VDC
D642C-3	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D643C-4	Tank Fwd Skin Inside	P	Temperature	"	3	0.5	" " "	"	"	"	"	"	"
D644C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D645C-4	Tank Aft Skin	P	Temperature	0° to 500°F	3	0.5	Chromel-Constanton T/C	18 MV	"	"	"	"	None
D646C-4	"	P	"	"	3	0.5	" " "	"	Needed	100 OHMS	2x10"	2x10^6	"
D647C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D648C-4	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D649C-5	Tank Aft Skirt Outside	P	Temperature	"	3	0.5							
D650C-5	"	P	"	"	3	0.5	" " "	"	"	"	5x10"	5x10^6	"
D651C-5	"	P	"	"	3	0.5	" " "	"	"	"	5x10"	5x10^6	"
D652C-5	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D653C-5	Tank Aft Skirt Inside	S	Temperature	0° to 500°F	3	0.5	" " "	"	"	"	"	"	"
D654C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D655C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D656C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D657C-5	Tank Aft Skirt Outside	S	Temperature	0° to 500°F	3	0.5	" " "	"	"	"	"	"	"
D658C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D659C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D660C-5	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D661C-5	Tank Aft Inside Insul	P	Temperature	-440° to 0°F	3	0.5	Plat. Res. Therm.	5 VDC with amp.	"	"	"	"	"
D662C-5	"	P	"	"	3	0.5	" " "	"	"	"	2x10"	2x10^6	13 MA at 28 VDC
D663C-5	Tank Aft Skin Inside	P	"	"	3	0.5	" " "	"	Needed	100 OHMS	2x10"	2x10^6	"
D664C-5	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D665C-5	Tank Base Inside Wall	P	"	"	3	0.5	" " "	"	"	"	1x10^{12}	1x10^7	"
D666C-5	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D667C-5	"	P	"	"	3	0.5	" " "	"	"	"	1x10^{12}	1x10^7	"
D668C-5	"	P	"	"	3	0.5	" " "	"	"	"	"	"	"
D669C-7	Interstage Aft Inside	S	Temperature	60 to 500°F	3	0.5	Chromel-Constanton T/C	18 MV	"	"	"	2x10^7	None
D670C-7	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"
D671C-7	"	S	"	"	3	0.5	" " "	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	± % ACCURACY	FREQ. RESP.	TRANSDUCER	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
D672C-7	Interstage Aft. Inside	S	Temperature	60 to 500°F	3	0.5cps	Chromel Constantan T/C	18 MV	Needed	100 OHMS	$1x10^{12}$	$2x10^{7}$	None
D673C-7	Interstage Aft. Outside	S	"	"	3	0.5	"	"	"	"	"	"	"
D674C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D675C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D676C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D677C-7	Interstage Fwd Inside	S	"	0° to 500°F	3	0.5	"	"	"	"	$5x10^{11}$	$5x10^{6}$	"
D678C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D679C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D680C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D681C-7	Interstage Fwd Outside	S	"	"	3	0.5	"	"	"	"	"	"	"
D682C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D683C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D684C-7	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D685C-5	Acturator & Bracket	S	Temperature	60° to 500°F	3	0.5	"	"	"	"	$2x10^{12}$	$2x10^{7}$	"
D686C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D687C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D688C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D689C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D690C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D691C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D692C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D693C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D694C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D695C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D696C-5	"	S	"	"	3	0.5	"	"	"	"	"	"	"
D697L-2	Equip. Bay Structure	S	Acoustic Level	120-190db	3	0.5	Piezoelectric High Intensity Mic.	5 VDC with amp	"	2000 OHMS	$2x10^{11}$	$2x10^{6}$	15 MA at 28 VDC
D698L-5	Tank Aft. Outside	S	"	"	3	0.5	"	"	"	"	$1x10^{12}$	$1x10^{7}$	"
D699L-7	Interstage Aft. Outside	S	"	"	3	0.5	"	"	"	"	"	$2x10^{7}$	"
B700M-2	Equip. Bay	P	Radiation - Neutron	10^{14} n/cm²sec		0.5	Radiation Detector Development Needed	5 VDC	"	2000 OHMS	$2x10^{11}$	$2x10^{6}$	100 MA at 28 VDC
E701M-2	"	P	"	"		0.5	"	"	"	"	"	"	"
E702M-3	Tank Fwd Dome	P	"	"		0.5	"	"	"	"	"	"	"
E703M-3	"	P	"	"		0.5	"	"	"	"	"	"	"
E704M-1	Nose Cone	P	"	"		0.5	"	"	"	"	"	"	"
E705M-5	Tank Aft	P	"	10^{14} n/cm²sec		0.5	"	"	"	"	$1x10^{12}$	$1x10^{7}$	"
E706M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E707M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E708M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E709M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E710M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E711M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E712M-5	"	P	"	"		0.5	"	"	"	"	"	"	"
E713M-5	"	P	"	"		0.5	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	±% ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
E714M-5	Tank Aft	P	Radiation-Neutron	10^{14} n/cm^2 sec	-	0.5	Radiation Detector Development Needed	5VDC	Needed	2000 Ohms	$1x10^{12}$	$1x10^{7}$	100 MA at 28VDC
E715M-5	Tank Aft			10^{14} n/cm^2 sec	-						$1x10^{12}$	$1x10^{7}$	
E716M-5	Tank Aft			10^{14} n/cm^2 sec	-						$1x10^{12}$	$1x10^{7}$	
E717M-5	Tank Aft			10^{14} n/cm^2 sec	-						$1x10^{12}$	$1x10^{7}$	
E718M-6	Engine			10^{14} n/cm^2 sec	-						$5x10^{13}$	$4x10^{8}$	
E719M-6	Engine		Neutron	10^{14} n/cm^2 sec	-						$5x10^{13}$	$4x10^{8}$	
E720M-2	Equip Bay		Gamma	10^{8} R/Hr	-						$2x10^{11}$	$2x10^{6}$	
E721M-2	Equip Bay				-						$2x10^{11}$	$2x10^{6}$	
E722M-3	Tank Fwd Dome				-						$2x10^{11}$	$2x10^{6}$	
E723M-3	Tank Fwd Dome				-						$2x10^{11}$	$2x10^{6}$	
E724M-1	Nose Cone				-						$2x10^{11}$	$2x10^{6}$	
E725M-5	Tank Aft			$5x10^{8}$ R/Hr	-						$1x10^{12}$	$1x10^{7}$	
E726M-5					-								
E727M-5					-								
E728M-5					-								
E729M-5					-								
E730M-5					-								
E731M-5					-								
E732M-5					-								
E733M-5					-								
E734M-5					-								
E735M-5					-								
E736M-5					-								
E737M-5	Tank Aft				-						$1x10^{12}$	$1x10^{7}$	
E738M-6	Engine				-						$5x10^{13}$	$4x10^{8}$	
E739M-6	Engine	P	Radiation-Gamma	$5x10^{8}$ R/Hr	-	0.5					$5x10^{13}$	$4x10^{8}$	
F740B-1	Nose Cone	S	Pressure	0-20 psia	3	8	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
F741B-1	Nose Cone α DP 2&3	S	Pressure	**0-20 psia**	3	8					$2x10^{11}$	$2x10^{6}$	
F742B-1	Nose Cone β DP 4&5	S	Pressure	**0-20 psia**	3	8					$2x10^{11}$	$2x10^{6}$	
F743G-2	Equip Bay Long	S-C	Acceleration	±10 g	2	15	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$2x10^{11}$	$2x10^{6}$	30 MA at 28VDC
F744G-2	Equip Bay Long	P	Acceleration	±2 g	2	15	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$2x10^{11}$	$2x10^{6}$	30 MA at 28VDC
F745P-5	Tank LH_2 Level	P	Liquid Level	0-100%	3	2	Liquid Level Development Needed	5VDC	Needed	2000 Ohms	$1x10^{12}$	$1x10^{7}$	100 MA at 28VDC
F746P-5	Tank LH_2 Level	P	Liquid Level								$1x10^{12}$	$1x10^{7}$	
F747P-5	Tank LH_2 Level	P	Liquid Level								$1x10^{12}$	$1x10^{7}$	
F748P-5	Tank LH_2 Level	P	Liquid Level								$1x10^{12}$	$1x10^{7}$	
F749B-1	Nose Cone Ext.	S	Pressure	0-5 psia	3	0.5	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
F750B-1	Nose Cone Ext.	S											
F751B-1	Nose Cone Ext.	S											
F752B-1	Nose Cone Ext.	S											
F753B-3	Tank Fwd Ext.	S											
F754B-3	Tank Fwd Ext.	S											
F755B-3	Tank Fwd Ext.	S	Pressure										

LOCKHEED MISSILES & SPACE COMPANY

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	± % ACCURACY	FREQ. RESP. (CPS)	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
F756B-3	Tank Fwd Ext	S	Pressure	0-5 psia	3	0.5	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 28VDC
F757B-5	Tank Aft Ext	S									$1x10^{12}$	$1x10^{7}$	
F758B-5	Tank Aft Ext	S											
F759B-5	Tank Aft Ext	S											
F760B-5	Tank Aft Ext	S				0.5							
G761B-5	Ullage Chamber	P-C		0-700 psia	3	2	Unbonded-Strain Gage	5VDC with Amp	Needed	2000 Ohms			30 MA at 28VDC
G762B-5	Ullage Chamber			0-700 psia	3	2	Unbonded-Strain Gage	5VDC with Amp	Needed	2000 Ohms			30 MA at 28VDC
G763B-5	Attitude Rocket Chamber			0-200 psia	3	2	Bourdon Tube-Pot	5VDC	None	5000 Ohms			1 MA at 5VDC
G764B-5	Attitude Rocket Chamber												
G765B-5	Attitude Rocket Chamber												
G766B-5	Attitude Rocket Chamber												
G767B-5	Attitude Rocket Chamber												
G768B-5	Attitude Rocket Chamber												
G769B-5	Actuator			0-100 psia	3	2	Unbonded-Strain Gage	5VDC with Amp	Needed	2000 Ohms			30 MA at 28VDC
G770B-5	Actuator			0-100 psia	3	2	Unbonded-Strain Gage	5VDC with Amp	Needed	2000 Ohms	$1x10^{12}$	$1x10^{7}$	30 MA at 28VDC
G771B-2	G&C Bearing Air Supply			0-3000 psia	3	0.5	Bourdon Tube-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
G772B-2	G&C Bearing Air Supply	P-C	Pressure	0-25 psia	3	0.5	Bellows-Pot	5VDC	None	5000 Ohms	$2x10^{11}$	$2x10^{6}$	1 MA at 5VDC
G773G-2	G&C Vel Signal	P	Acceleration	0-7.5 g	1 Ft/Sec^2	2000			VOLTAGE FROM GUIDANCE & CONTROL PCKG.				
G774G-2	**G&C Vel Signal**	P	Acceleration	1 g	1 Ft/Sec^2	2000							
G775G-2	**G&C Vel Signal**	P	Acceleration	1 g	1 Ft/Sec^2	2000							
G776G-2	G&C Signal	P-C	Acceleration	±2 g	1	2							
G777G-3	Tank Fwd Lat.	P-C	Acceleration	±1 g	2	15	Gas Damped Unbonded Strain Gage	5VDC with Amp	Needed	2000 Ohms	$2x10^{11}$	$2x10^{6}$	30 MA at 28VDC
G778G-3	Tank Fwd Nor.	P-C	Acceleration								$2x10^{11}$	$2x10^{6}$	
G779G-5	Tank Aft Lat.	P	Acceleration								$1x10^{12}$	$1x10^{7}$	
G780G-5	Tank Aft Nor.	P	Acceleration								$1x10^{12}$	$1x10^{7}$	
G781N-2	Pitch	P	Rate -	±10°/Sec	3	15					$2x10^{11}$	$2x10^{6}$	
G782N-2	Yaw	P	Rate -	±10°/Sec	3	15					$2x10^{11}$	$2x10^{6}$	
G783N-2	Roll	P	Rate -	±10°/Sec	3	15					$2x10^{11}$	$2x10^{6}$	
G784K-2	Guidance Computer Pos.	P	Voltage	-	-	0.5			VOLTAGE FROM GUIDANCE & CONTROL PCKG.				
G785K-2	Guidance Computer Pos.	P	Voltage	-	-	0.5							
G786K-2	Guidance Computer Pos.	P	Voltage	-	-	0.5							
G787K-2	Guidance Computer Velocity	P	Voltage	-	-	0.5							
G788K-2	Guidance Computer Velocity	P	Voltage	-	-	0.5							
G789K-2	Guidance Computer Velocity	P	Voltage	-	-	0.5							
G790A-2	Pitch Angle	P-C	Position	0-360°	0.5	8							
G791A-2	Yaw Angle	P-C	Position	0-360°	0.5	8							
G792A-2	Roll Angle	P-C	Position	0-360°	0.5	8							
G793A-2	Nuclear Engine	MP	Position	0-3.5°	3	15							
G794A-2	Nuclear Engine	MP	Position	0-3.5°	3	15							
G795C-2	Electronics Pkg	P	Temperature	-65 to +200°F	3	0.5	Plat. Res. Therm.	5VDC with Amp	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	13 MA at 28VDC
G796C-2	Electronics Pkg	P	Temperature	-65 to +200°F	3	0.5	Plat. Res. Therm.	5VDC with Amp	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	13 MA at 28VDC
G797C-2	Electronics Pkg	P	Temperature	-65 to +200°F	3	0.5	Plat. Res. Therm.	5VDC with Amp	Needed	100 Ohms	$2x10^{11}$	$2x10^{6}$	13 MA at 28VDC

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
G798C-2	Electronics Package	P	Temperature	-65 to 200 F	± 3	0.5cps	Plat.Res.Therm.	5 VDC with amp	Needed	100 OHMS	$2x10^{11}$	$2x10^{6}$	13 MA at 28 VDC
G799C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G800C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G801C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G802C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G803C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G804C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G805C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G806C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G807C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G808C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G809C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G810C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G811C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G812C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G813C-2	"	"	"	"	"	"	"	"	"	"	"	"	"
G814C-2	Electronics Package	"	"	"	"	"	"	"	"	"	"	"	"
G815C-5	Actuator	"		60-500°F	"	"	Chromel-Constantan T/C	"	"	"	$2x10^{12}$	$2x10^{7}$	None
G816C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G817C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G818C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G819C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G820C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G821C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G822C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G823C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G824C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G825C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G826C-5	"	"	"	"	"	"	"	"	"	"	"	"	"
G827J-2	Drum Timing Signal	"	Sequence	-	"	"	----------	----------	VOLTAGE FROM GUIDANCE AND CONTROL PACKAGE	----------	----------	----------	----------
G828K-2	Guidance Supply +30V	"	Voltage	0 to 32V	"	"	"	"	"	"	"	"	"
G829K-2	Guidance Supply -30V	"	"	-32 to 0V	"	"	"	"	"	"	"	"	"
G830K-2	Guidance and Control Analog	"	"	0-5V	"	8	"	"	"	"	"	"	"
G831K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G832K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G833K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G834K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G835K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G836K-2	Guidance Horizon Scanner	"	"	"	"	2	"	"	"	"	"	"	"
G837K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"
G838K-2	Guidance Control Computer	"	"	"	"	8	"	"	"	"	"	"	"
G839K-2	" " "	"	"	"	"	"	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	± ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
G840K-2	Guidance Control Computer	P	Voltage	0-5 V	±3	8 cps	VOLTAGE FROM GUIDANCE AND CONTROL PACKAGE						
G841K-2	Guidance Control Computer	P	Voltage	"	"	8	"	"	"	"	"	"	"
G842K-2	Guidance Control Computer	P	Voltage	"	"	8	"	"	"	"	"	"	"
G843K-2	Guidance Control Computer	P	Voltage	"	"	8	"	"	"	"	"	"	"
G844K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G845K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G846K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G847K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G848K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G849K-2	Guidance Signal Processor	P	Voltage	"	"	8	"	"	"	"	"	"	"
G850J-2	Guidance Eng. Lock	P	Sequence	"	"	15	"	"	"	"	"	"	"
G851J-2	Guidance Eng. Lock	P	Sequence	"	"	15	"	"	"	"	"	"	"
G852J-2	Guidance & Control Computer	P	Sequence	"	"	15	"	"	"	"	"	"	"
G853J-2	Guidance & Control Computer	P	Sequence	"	"	15	"	"	"	"	"	"	"
G854J-2	Guidance & Control Computer	P	Sequence	"	"	15	"	"	"	"	"	"	"
G855J-2	Guidance & Control Computer	P	Sequence	"	"	15	"	"	"	"	"	"	"
G856J-2	Guidance & Control Computer	P	Sequence	"	"	15	"	"	"	"	"	"	"
H857B-5	Fuel, Attitude Control Tank	P	Pressure	0-300 PSIA	"	2	Bourdon Tube Pot	5 VDC	None	5000 OHMS	$1x10^{12}$	$1x10^{7}$	1 MA at 5 VDC
H858B-5	Fuel, Attitude Control Tank	P	Pressure	"	"	2	" " "	"	"	"	"	"	"
H859B-5	Oxidizer, Attit.Control Tank	P	Pressure	"	"	2	" " "	"	"	"	"	"	"
H860B-5	Oxidizer, Attit.Control Tank	P	Pressure	"	"	2	" " "	"	"	"	"	"	"
H861B-5	Nitrogen, Attit.Control Tank	P	Pressure	0-4000 PSIA	"	2	" " "	"	"	"	"	"	"
H862B-5	Nitrogen, Attit.Control Tank	P	Pressure	"	"	2	" " "	"	"	"	"	"	"
H863C-5	Oxidizer	P	Temperature	-60°to +350°F	"	2	Chromel-Constantan T/C	15 MV	Needed	100 OHMS	"	"	None
H864C-5	Oxidizer	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H865C-5	Fuel	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H866C-5	Fuel	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H867C-5	Nitrogen	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H868C-5	Nitrogen	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H869C-5	Ullage Chamber Att. Rocket	P	Temperature	-60°to +2000°F	"	2	" " "	80 MV	"	"	"	"	"
H870C-5	Ullage Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H871C-5	Pitch Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H872C-5	Pitch Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H873C-5	Roll and Yaw Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H874C-5	Roll and Yaw Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H875C-5	Roll and Yaw Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H876C-5	Roll and Yaw Chamber Att. Rocket	P	Temperature	"	"	2	" " "	"	"	"	"	"	"
H877D-5	Fuel Attitude	P	Flow Rate	0-7 lb/s	"	8	Mass Flow Meter Dev.	5 VDC	"	2000 OHMS	"	"	100 MA at 28 VDC
H878D-5	Fuel Attitude	P	Flow Rate	"	"	8	" " "	"	"	"	"	"	"
H879D-5	Oxidizer Attitude	P	Flow Rate	"	"	8	" " "	"	"	"	"	"	"
H880D-5	Oxidizer Attitude	P	Flow Rate	"	"	8	" " "	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
H331A-5	Att. Control Tank Valve	P	Position	On-Off	± 3	15cps	----------	CONDITIONED VOLTAGE TO THE TM PACKAGE					
H332A-5	Att. Control Tank Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H333A-5	Att. Control Tank Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H334A-5	Att. Control Tank Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H335A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H336A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H337A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H338A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H339A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H390A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H391A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
H392A-5	Chamber Valve	P	Position	"	"	"	"	"	"	"	"	"	"
J393K-2	Transmitter RF	S	Power	0-10 Watts	"	0.5	"	"	"	"	"	"	"
J894K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J895K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J896K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J897K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J898K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J899K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J900K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J901K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J902K-2	Transmitter RF	S	Power	"	"	"	"	"	"	"	"	"	"
J903K-2	Transmitter Power Supply	S	Power	0-350 V	"	"	"	"	"	"	"	"	"
J904K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J905K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J906K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J907K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J908K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J909K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J910K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J911K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
J912K-2	Transmitter Power Supply	S	Power	"	"	"	"	"	"	"	"	"	"
K913K-2	Enable Eng.Start & Restart	MP	Voltage	0-5 V	"	"	"	"	"	"	"	"	"
K914K-2	Initiate Eng.Start & Restart	MP	Voltage	"	"	"	"	"	"	"	"	"	"
K915K-2	Eng. Start &Restart Override	MP	Voltage	"	"	"	"	"	"	"	"	"	"
K916K-2	Engine Shutdown	MP	Voltage	"	"	"	"	"	"	"	"	"	"
K917K-2	Engine Shutdown Override	MP	Voltage	"	"	"	"	"	"	"	"	"	"
L913K-2	Destruct Accept Pulse	MP	Voltage	"	"	"	"	"	"	"	"	"	"
L919K-2	Destruct Accept Pulse	MP	Voltage		"	"	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
923													
924													
925													
926													
927													
928													
L929C-2	Engine Destruct Pkg.	MP	Temperature	–	±3	0.5 cps	Chromel-Constantan T/C	10 MV	Needed	100 OHMS			None
L930K-2	Eng. Dest. Signal Level #1	MP	Voltage	-75 to 0 VDC	"	"	----------	CONDITIONED VOLTAGE FED TO TM					----------
L931K-2	Eng. Dest. Signal Level #2	MP	Voltage	"	"	"	----------	CONDITIONED VOLTAGE FED TO TM					----------
L932K-2	Eng. Safe Arm Dest. Mon. #1	MP	Voltage	0(S), .3(A), .6(D)	"	"	----------	CONDITIONED VOLTAGE FED TO TM					----------
L933K-2	Eng. Safe Arm Dest. Mon. #2	MP	Voltage	"	"	"	"	"	"	"	"	"	"
L934K-2	Eject.Eng.Dest. Pkg.	MP	Voltage	0-5 V	"	"	"	"	"	"	"	"	"
M935K-2	Beacon Trans. RF	P	Power	–	"	"	"	"	"	"	"	"	"
M936K-2	Beacon Rec. Mon.	P	Power	–	"	"	"	"	"	"	"	"	"
N937K-2	Azusa Trans. RF	P	Power	–	"	"	"	"	"	"	"	"	"
N938K-2	Azusa Rec. Mon.	P	Power	–	"	"	"	"	"	"	"	"	"
P939K-2	Main Battery	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P940K-2	Main Battery	S	Voltage	"	"	"	"	"	"	"	"	"	"
P941K-2	Battery Total	S	Current	0-150 AMP	"	"	"	"	"	"	"	"	"
P942K-2	Interstage J Box	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P943K-2	Engine J Box	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P944K-2	Control System J Box	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P944K-2	Control System J Box	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P945K-2	Control System J Box	S	Voltage	0-32 V	"	"	"	"	"	"	"	"	"
P946K-2	Converter +28 V	S	Voltage	0 to + 30 V	"	"	"	"	"	"	"	"	"
P947K-2	Converter -28 V	S	Voltage	-30 to 0 V	"	"	"	"	"	"	"	"	"
R948A-8	S-IC Engines	S	Position	±6°	"	15	"	"	"	"	"	"	"
R949A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R950A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R951A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R952A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R953A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R954A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R955A-8	S-IC Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R956A-9	S-II Engines	S	Position	± 7.5°	"	"	"	"	"	"	"	"	"
R957A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R958A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R959A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R960A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R961A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R962A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R963A-9	S-II Engines	S	Position	"	"	"	"	"	"	"	"	"	"
R964J-8	S-I Separation	P	Sequence	0-5 V	"	0.5	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
R965J-9	S-II Separation	P	Sequence	0-5 V	± 3	0.5cps	----------	CONDITIONED VOLTAGE FROM GUIDANCE AND CONTROL PACKAGE					
R966K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R967K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R968K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R969K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R970K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R971K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R972K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R973K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R974K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R975K-8	Launch Event	P	Voltage	"	"	"	"	"	"	"	"	"	"
R976N-8	Guidance Pitch S-I	S	Rate	± 10°/sec	3	15	"	"	"	"	"	"	"
R977N-8	Guidance Yaw S-I	S	Rate	" "	"	"	"	"	"	"	"	"	"
R978G-8	Guidance Nor S-I	S	Acceleration	± 1 G	2	"	"	"	"	"	"	"	"
R979G-8	Guidance Lat S-I	S	Acceleration	" "	"	"	"	"	"	"	"	"	"
R980N-9	Guidance Pitch S-II	S	Rate	± 10°/sec	3	"	"	"	"	"	"	"	"
R981N-9	Guidance Yaw S-II	S	Rate	" "	"	"	"	"	"	"	"	"	"
R982G-9	Guidance Nor S-II	S	Acceleration	± 2 G	2	"	"	"	"	"	"	"	"
R983G-9	Guidance Nor S-II	S	Acceleration	" "	"	"	"	"	"	"	"	"	"
R984G-9	Guidance Nor S-II	S	Acceleration	"	"	"	"	"	"	"	"	"	"
R985G-9	Guidance Lat S-II	S	Acceleration	"	"	"	"	"	"	"	"	"	"
R986G-9	Guidance Lat S-II	S	Acceleration	"	"	"	"	"	"	"	"	"	"
R987G-9	Guidance Lat S-II	S	Acceleration	"	"	"	"	"	"	"	"	"	"
R988B-9	Interstage Ext	S	Pressure	0-20 PSIA	3	0.5	"	"	"	"	"	"	"
R989B-9	Interstage Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R990B-9	Interstage Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R991B-9	Interstage Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R992B-8	S-IC Base Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R993B-8	S-IC Base Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R994B-8	S-IC Base Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R995B-8	S-IC Base Ext	S	Pressure	"	"	"	"	"	"	"	"	"	"
R996R-8	S-IC Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R997R-8	S-IC Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R998R-8	S-IC Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R999R-8	S-IC Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1000R-8	S-IC Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1001R-9	S-II Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1002R-9	S-II Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1003R-9	S-II Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1004R-9	S-II Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"
R1005R-9	S-II Stage Engs.	S	Thrust	—	"	—	"	"	"	"	"	"	"

Table 1-1

VEHICLE MEASUREMENT LIST (cont.)

VEHICLE MEASUREMENT NO.	MEASUREMENT NAME	TYPE	PARAMETER	RANGE	% ACCURACY	FREQ. RESP.	TRANSDUCER TYPE	OUTPUT FULL SCALE	SIGNAL CONDITIONING	OUTPUT IMPEDANCE	RADIATION ENVIRONMENT NEUTRONS NVT	RADIATION ENVIRONMENT GAMMA R	POWER REQUIREMENTS
R1006E-8	S-IC Base	S	Strain	0 to .01 in/in	3	100	---------- CONDITIONED VOLTAGE TO BE SUPPLIED ----------						
R1007E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1008E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1009E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1010E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1011E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1012E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1013E-8	S-IC Base	S	Strain	"	"	"	"	"	"	"	"	"	"
R1014E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1015E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1016E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1017E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1018E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1019E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1020E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1021E-9	Interstage	S	Strain	"	"	"	"	"	"	"	"	"	"
R1022E-8	S-IC Hold Down Clamps	S	Strain	–	–	–	"	"	"	"	"	"	"
R1023E-8	S-IC Hold Down Clamps	S	Strain	–	–	–	"	"	"	"	"	"	"
R1024E-8	S-IC Hold Down Clamps	S	Strain	–	–	–	"	"	"	"	"	"	"
R1025E-8	S-IC Hold Down Clamps	S	Strain	–	–	–	"	"	"	"	"	"	"
E1026S-7	H_2 Level Interstage	P	H_2 Gas Level	–	3	0.5	H_2 Gas Detector To be developed	5 VDC	Needed	2000 OHMS	–	–	100 MA at 28 VDC
E1027S-7	H_2 Level Interstage	P	H_2 Gas Level	–	"	"	"	"	"	"	–	–	"
E1028S-2	H_2 Level Equip. Bay	P	H_2 Gas Level	–	"	"	"	"	"	"	–	–	"
E1029S-1	H_2 Level Nose Cone	P	H_2 Gas Level	–	"	"	"	"	"	"	–	–	"

Section 2

COMMUNICATIONS SYSTEMS DESIGN

2.1 TELEMETRY SYSTEMS

The development test flights of the RIFT S-N Stage will require extensive structural and environmental monitoring instrumentation. A preliminary list of transducers is shown in Table 1-1. It is expected that, due to the combined cryogenic-nuclear environment of the RIFT vehicle, the instrumentation requirements will change periodically, and the telemetry channels may be reallocated as required.

The RIFT telemetry system ultimately may be required to transmit over 1500 parameters. The present telemetry system of 13 TM/RF links would then need to be expanded by additional TM/RF links.

The telemetry system as presently visualized will consist of nine PAM-FM-FM links having the basic system characteristics of the AN/DKT-8(XO-6C) telemetry set, and two PAM-FM-FM links which use 70 kc subcarrier oscillators deviated ±30 percent, a quadrupled commutation rate, 30 channels, and a sampling rate of 120 samples/sec. This non-standard format can be ground decoded with standard IRIG techniques after changing the speed of playback to one quarter of the recording speed and using a tunable subcarrier discriminator such as the EMR-97D. This method of decommutation has been used for Saturn telemetry

processing. Data transmitted in this manner cannot normally be used for real-time display. The remaining telemetry systems, SS-FM and PCM-FM, are described under a separate heading. Table 2-1 is a tabulation of channel assignment versus frequency response. The requirement to use PAM-FM-FM and SS-FM telemeters limits the data accuracy to 3 to 5 percent. A block diagram of the RIFT S-N Stage telemetry system is shown in Fig. 2-1.

2.1.1 PAM-FM-FM Telemetry

A total of 11 PAM-FM-FM telemetry links will be used.

Two of these telemetry links will not conform to IRIG telemetry standards as they use high-speed commutation in the 70 kc +30 percent channels, (as explained in 2.1 above) and direct modulation of the modulator bus by turbine speed couplers. Channel 13 of both telemeters is commutated by a 30-channel, 2.5 samples/sec commutator to provide IRIG sync signals, two calibrate points, and 26 data channels capable of 1 cps response. These channels will be used to transmit 0 to 0.5 cps data. A block diagram of this telemetry link is shown in Fig. 2-2.

Three telemetry links will feature standard IRIG direct data and commutated data channel assignments. Channels 13 and 14 will be commutated, each by a 30-channel, 2.5 samples/sec commutator to provide IRIG sync signals, two calibrate points, and 26 data channels with the capability of 1 cps response for the transmission of 0 to 0.5 cps data. A block diagram of this telemetry link is shown in Fig. 2-3.

Table 2-1

TELEMETRY LINKS – CHANNEL ASSIGNMENTS

SS/FM Chan.	FM/FM Chan.	SS/FM Link	PAM FM/FM Link 1	PAM FM/FM Link 2	PAM FM/FM Link 3	PAM FM/FM Link 4	PAM FM/FM Link 5	PAM FM/FM Link 6	PAM FM/FM Link 7	PAM FM/FM Link 8	PAM FM/FM Link 9	PAM FM/FM Link 10	PAM FM/FM Link 11
1	1	30 x 30 sps Commut. 26 Ch/12 cps	Turbine	Turbine	2 cps Direct	2 cps Direct	2 cps Direct	Spare	Spare	Spare	Spare	0.5 cps Direct	0.5 cps Direct
2	2	30 x 30 sps Commut. 26 Ch/12 cps	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct
3	3	30 x 30 sps Commut. 26 Ch/12 cps	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct
4	4	30 x 30 sps Commut. 26 Ch/12 cps	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct
5	5	30 x 30 sps Commut. 26 Ch/12 cps	8 cps Direct	8 cps Direct	8 cps Direct	8 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct
6	6	50-3000	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct
7	7	50-3000	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct
8	8	50-3000	15 cps Direct	15 cps Direct	Spare	Spare	Spare	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct	15 cps Direct
9	9	50-3000	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct	50 cps Direct
10	10	50-3000	50 cps Direct	50 cps Direct	Spare	Spare	Spare	Spare	Spare	Spare	Spare	50 cps Direct	50 cps Direct
11	11	50-3000	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct
12	12	50-3000	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	100 cps Direct	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps
13	13	50-3000	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps
14	14	50-3000	30 x 5 sps 26 Ch/2cps	30 x 5 sps 26 Ch/2cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	30 x 2.5 sps 26 Ch/0.5cps	250 cps Direct	250 cps Direct
15	15	50-3000	30 x 120 sps 26 Ch/15 cps (70 kc ±30%)	30 x 120 sps 26 Ch/15 cps (70 kc ±30%)	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct
	16				250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct
	17				250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct
	18				250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	250 cps Direct	18 x 25 sps 14 Ch/8 cps	18 x 25 sps 14 Ch/8 cps

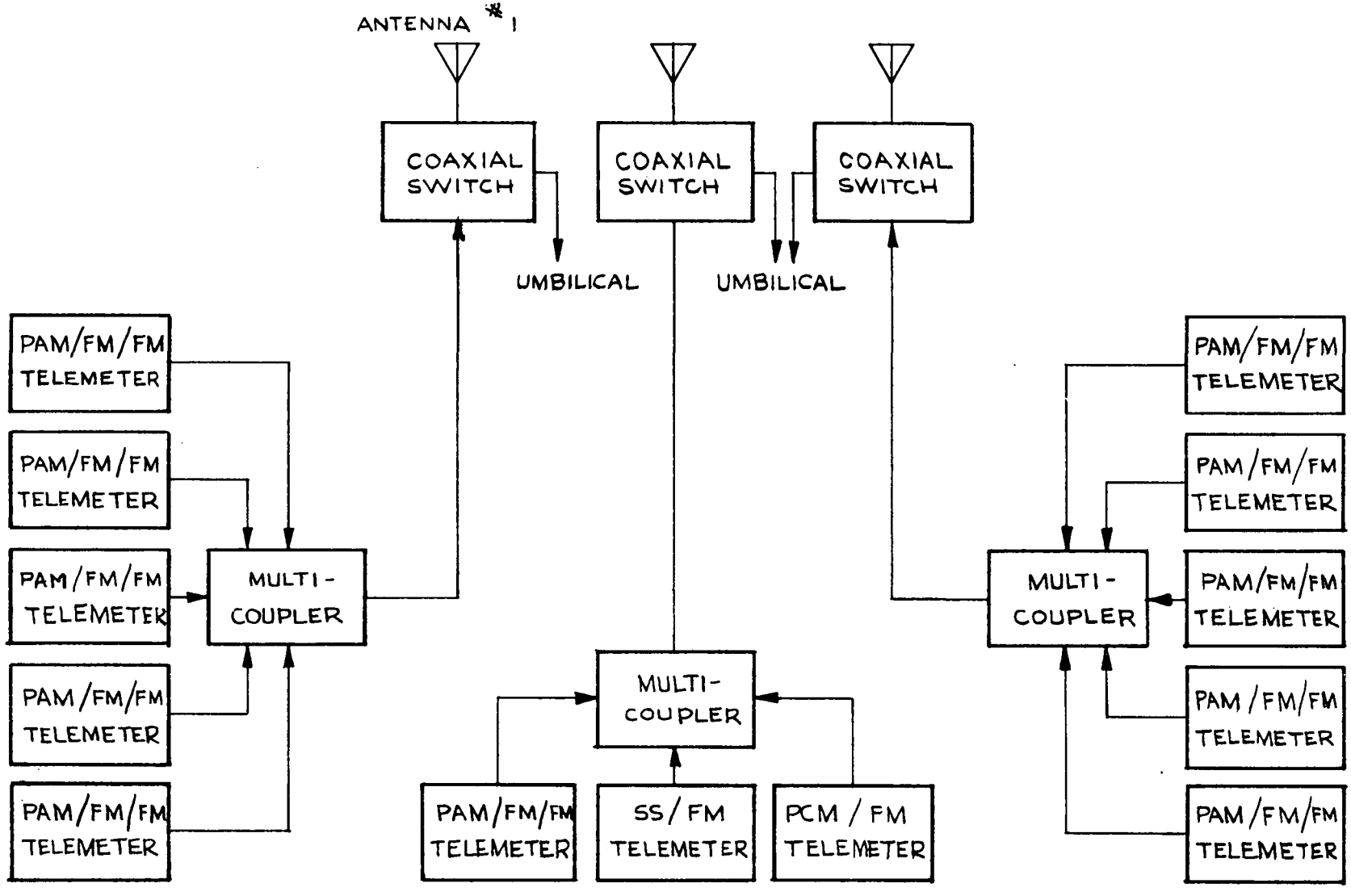

Fig. 2-1 Block Diagram, Telemetry System

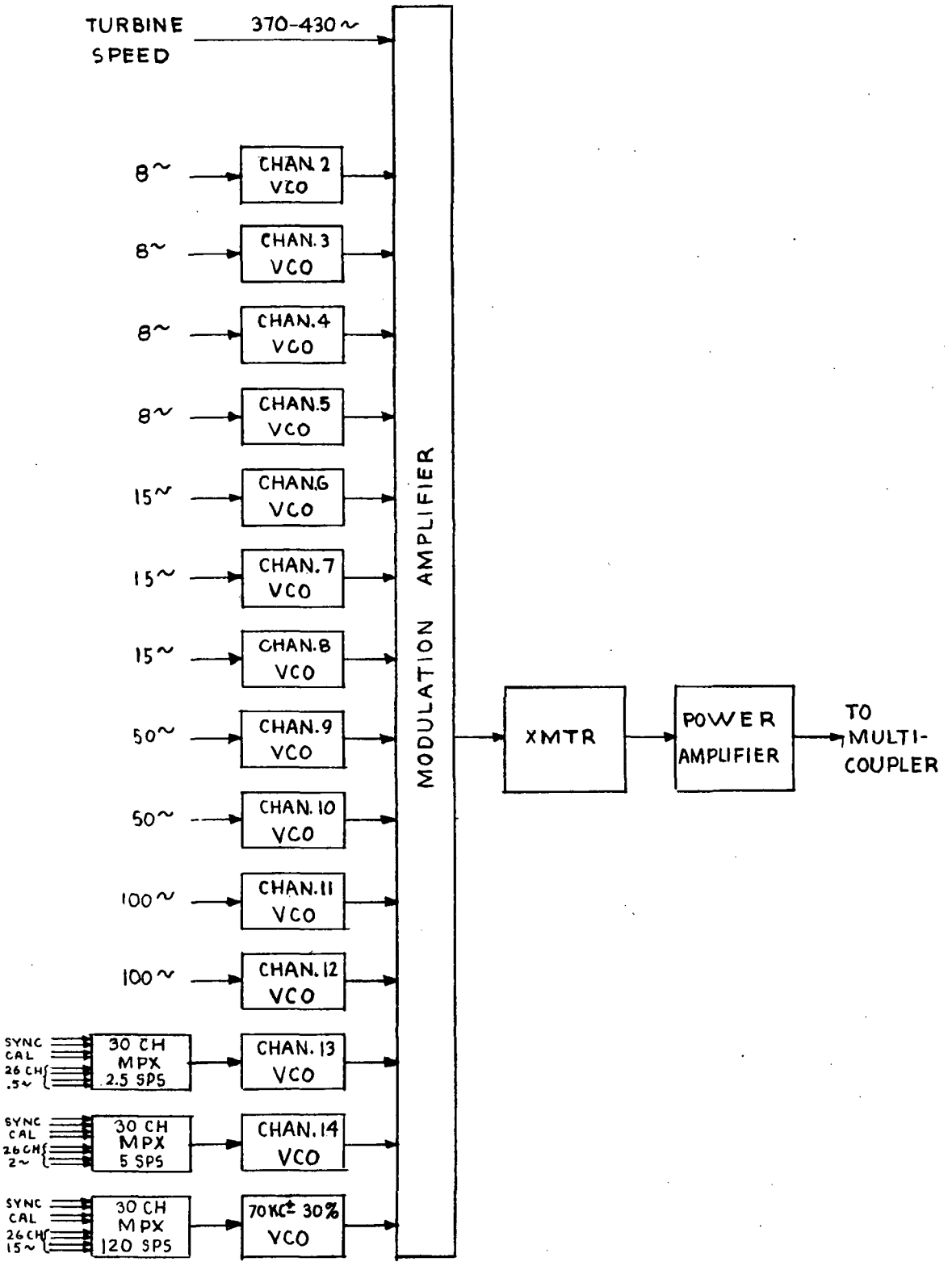

Fig. 2-2 PAM/FM-FM Telemeter, Configuration A

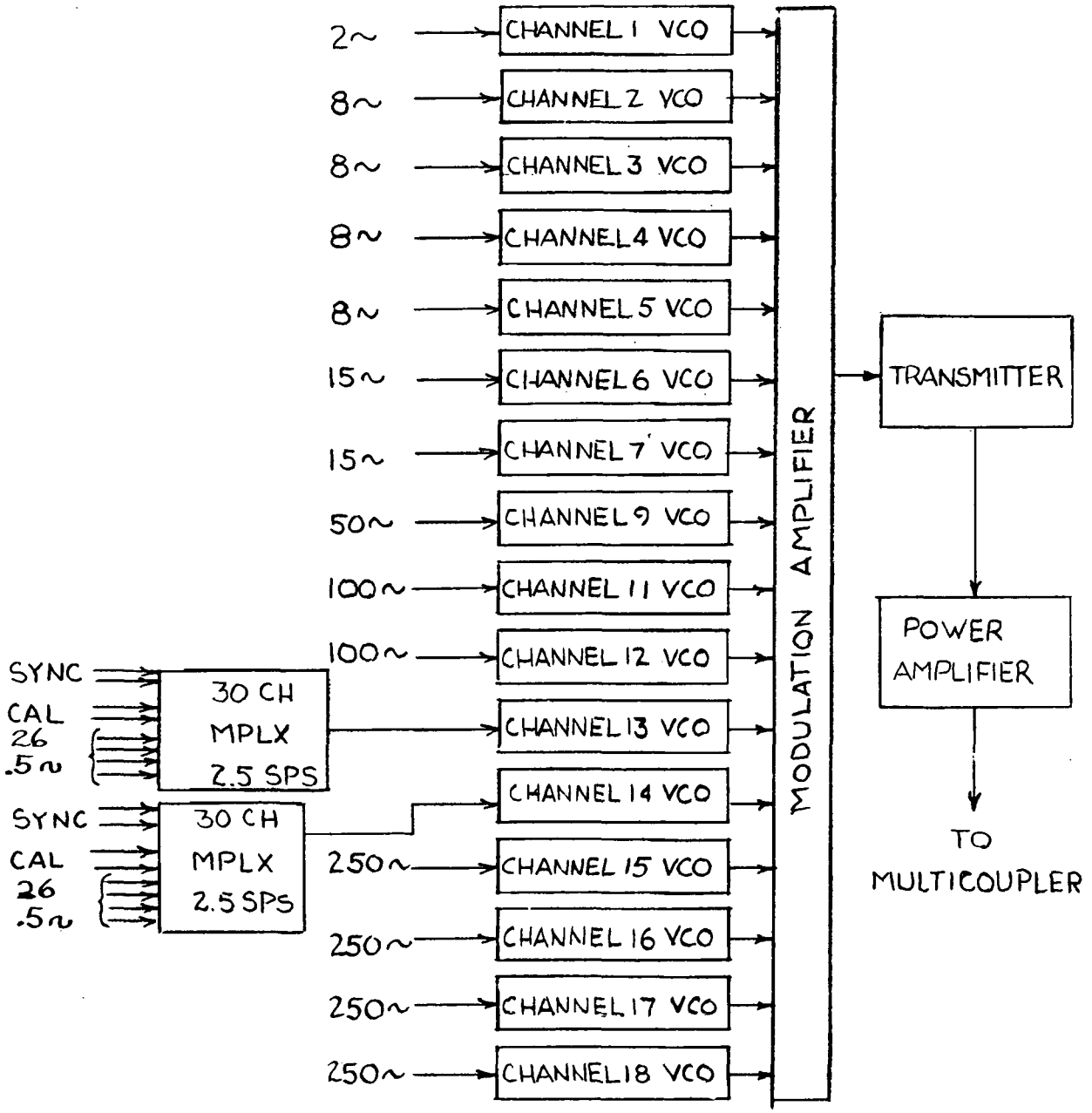

Fig. 2-3 PAM/FM-FM Telemeter, Configuration B

Four telemetry links will feature standard IRIG direct data and commutated data channel assignments. Commutated channels will be channels 12, 13, and 14. Each will be commutated by a 30-channel, 2.5 samples/sec commutator to provide two sync and two calibrate points and 26 data channels having the capability of 1 cps response, for the transmission of 0 to 0.5 cps data.

A block diagram of this telemetry link is shown in Fig. 2-4.

Two telemetry links will feature standard IRIG direct data and commutated data channel assignments. Channels 13 and 14 will be commutated by a 30-channel, 2.5 samples/sec commutator to provide two sync and two calibrate points and 26 data channels having the capability of 1 cps response for the transmission of 0 to 0.5 cps data. Channel 18 will be commutated by an 18-channel, 25 samples/sec commutator to provide two sync and two calibrate points and 14 data channels having the capability of 10 cps response for the transmission of 0 to 8 cps data.

A block diagram of this telemetry link is shown in Fig. 2-5.

2.1.2 SS-FM TELEMETRY

2.1.2.1 Characteristics of Present Equipment

Present SSB multiplexing equipment combines the inputs from up to 15 information channels by SSB modulating 15 discrete carrier frequencies and then summing them. The carrier frequencies are given by 1.74 + (N-1) 4.74 kc, where N is the channel number (1-15). In addition to the 15 information channels, a pilot signal (75.83-kc sine wave) and an auxiliary channel (0-42 kc) are provided.

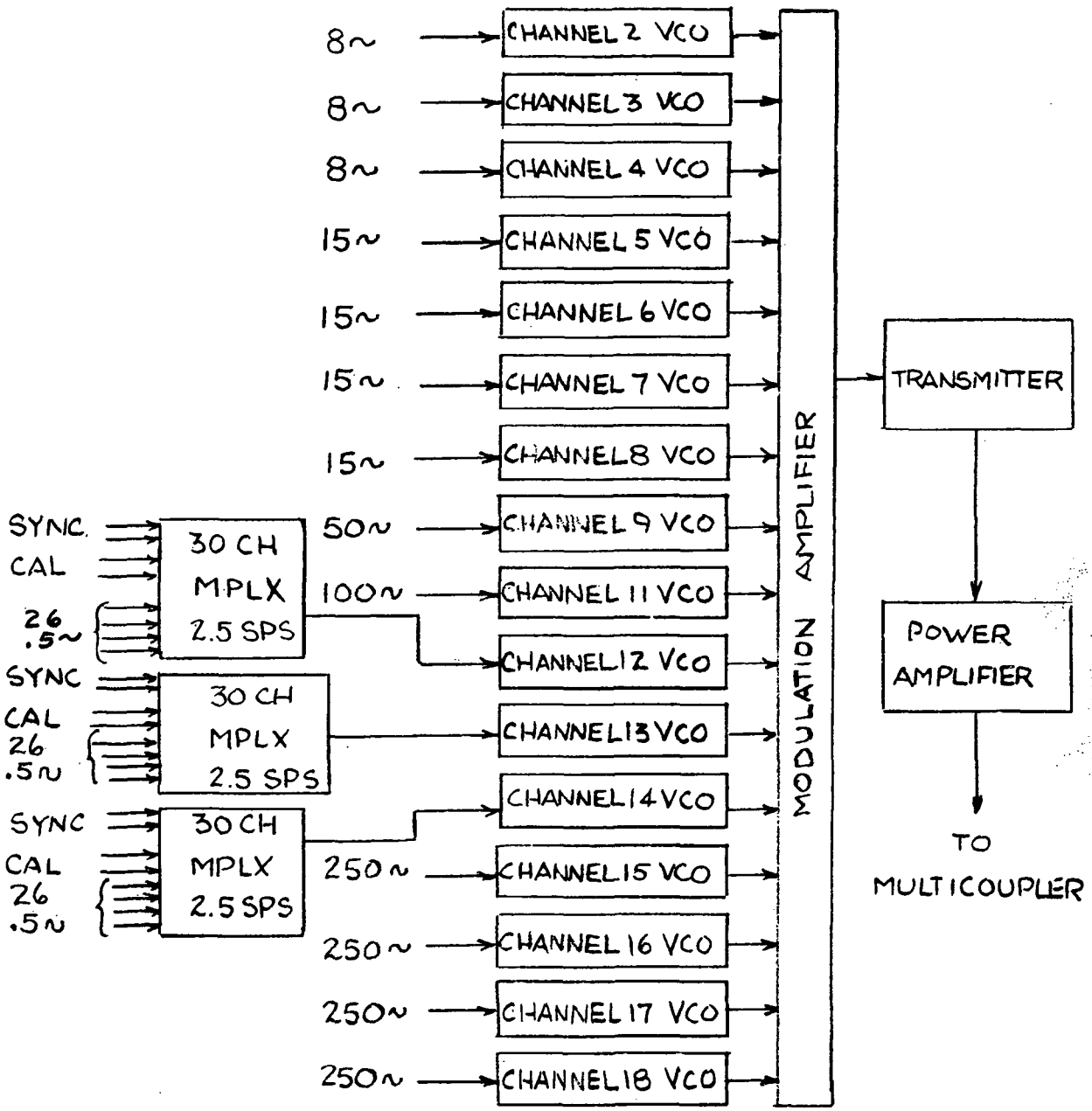

Fig. 2-4 PAM/FM-FM Telemeter, Configuration C

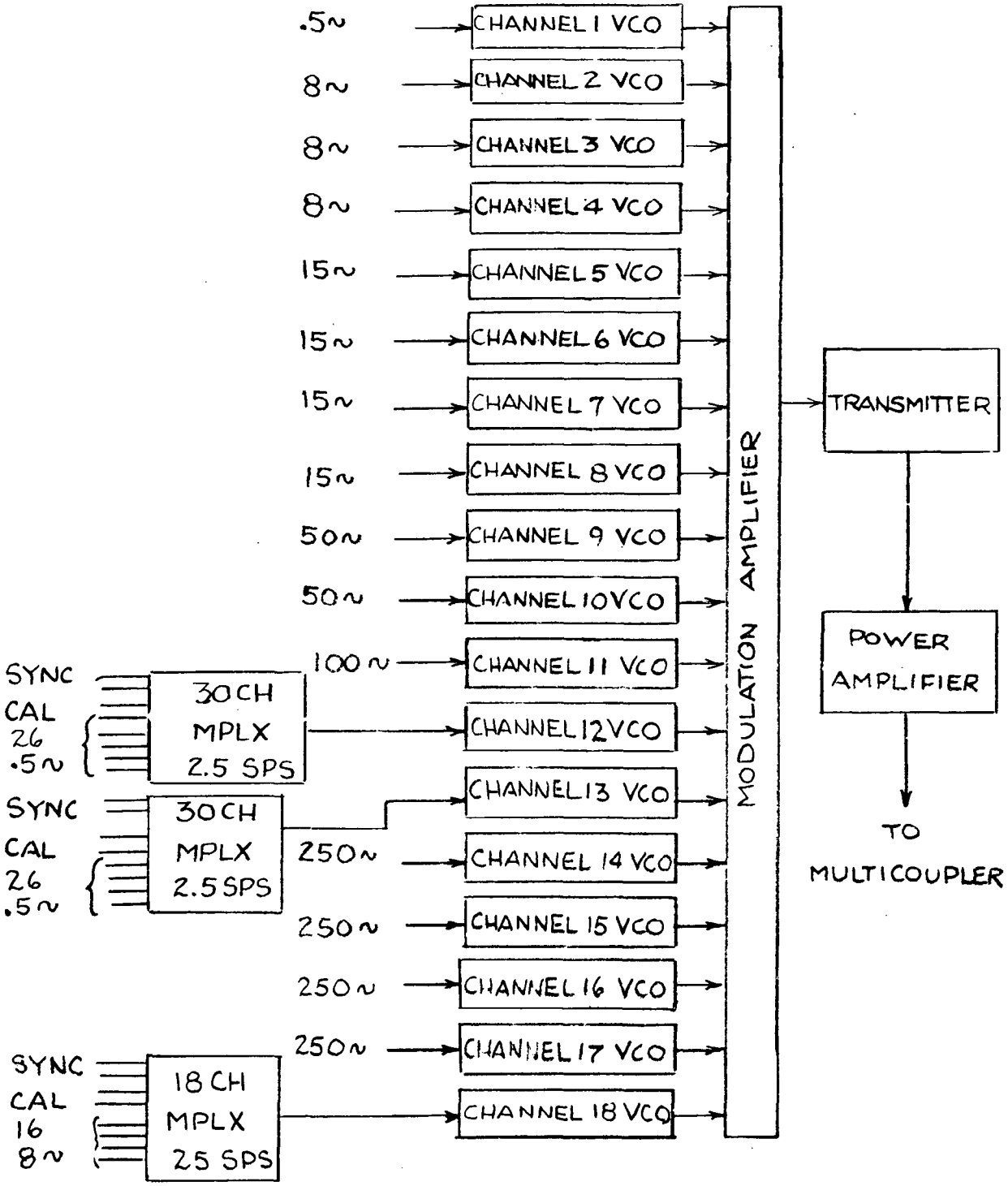

Fig. 2-5 PAM/FM-FM Telemeter, Configuration D

The pilot signal serves to lock the ground equipment frequency and phase to the vehicle-borne equipment and to provide a scale reference for correcting the level of the composite signal.

The equipment can be divided generally into channel units and common equipment. A channel unit carries information for one channel only, while common equipment applies to all channels. A channel unit consists of a balanced modulator whose carrier input is 455 kc, a mechanical filter that passes the upper side band only, and another balanced modulator that translates the signal into the proper location in the base band. Figure 2-6 shows one of the channel units.

The common equipment consists of a 455 kc carrier generator, the second modulator carrier generator, and the pilot generator. These units are all operated from a 910 kc crystal oscillator. In addition there are adders, amplifiers, and an AGC unit to prepare the signals for transmission on an FM carrier. Figure 2-7 shows the oscillator system, and Fig. 2-8 shows the complete multiplexing system.

Since the vibration amplitude will vary greatly during different phases of flight, the AGC was introduced to provide overload protection during initial high-amplitude phases and to prevent large frequency deviations during later periods. In the vehicle unit the AGC is controlled by the sum of all inputs, and in the ground equipment it is controlled by the pilot signal; thus all signals are restored to their proper proportions.

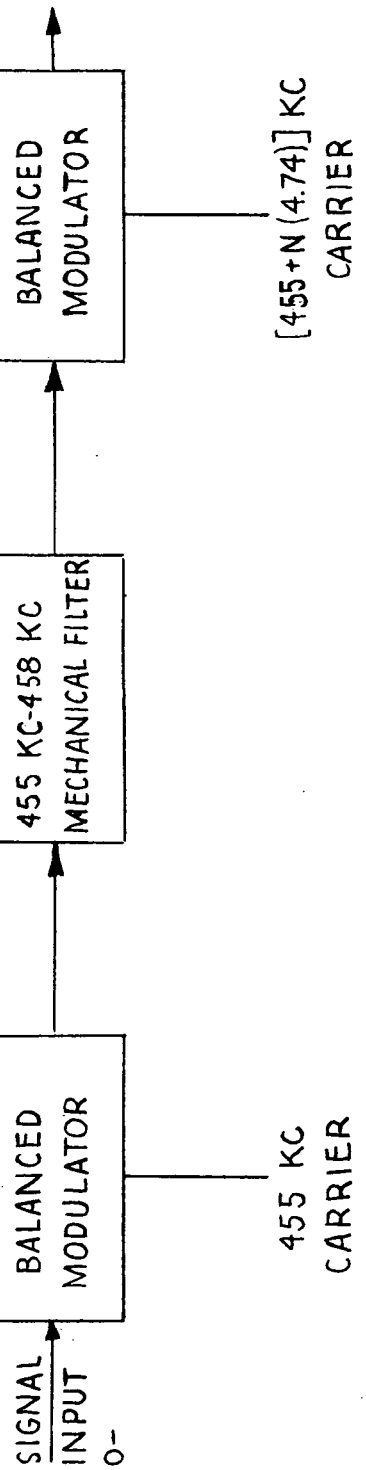

Fig. 2-6 Block Diagram, SS-FM Channel Unit

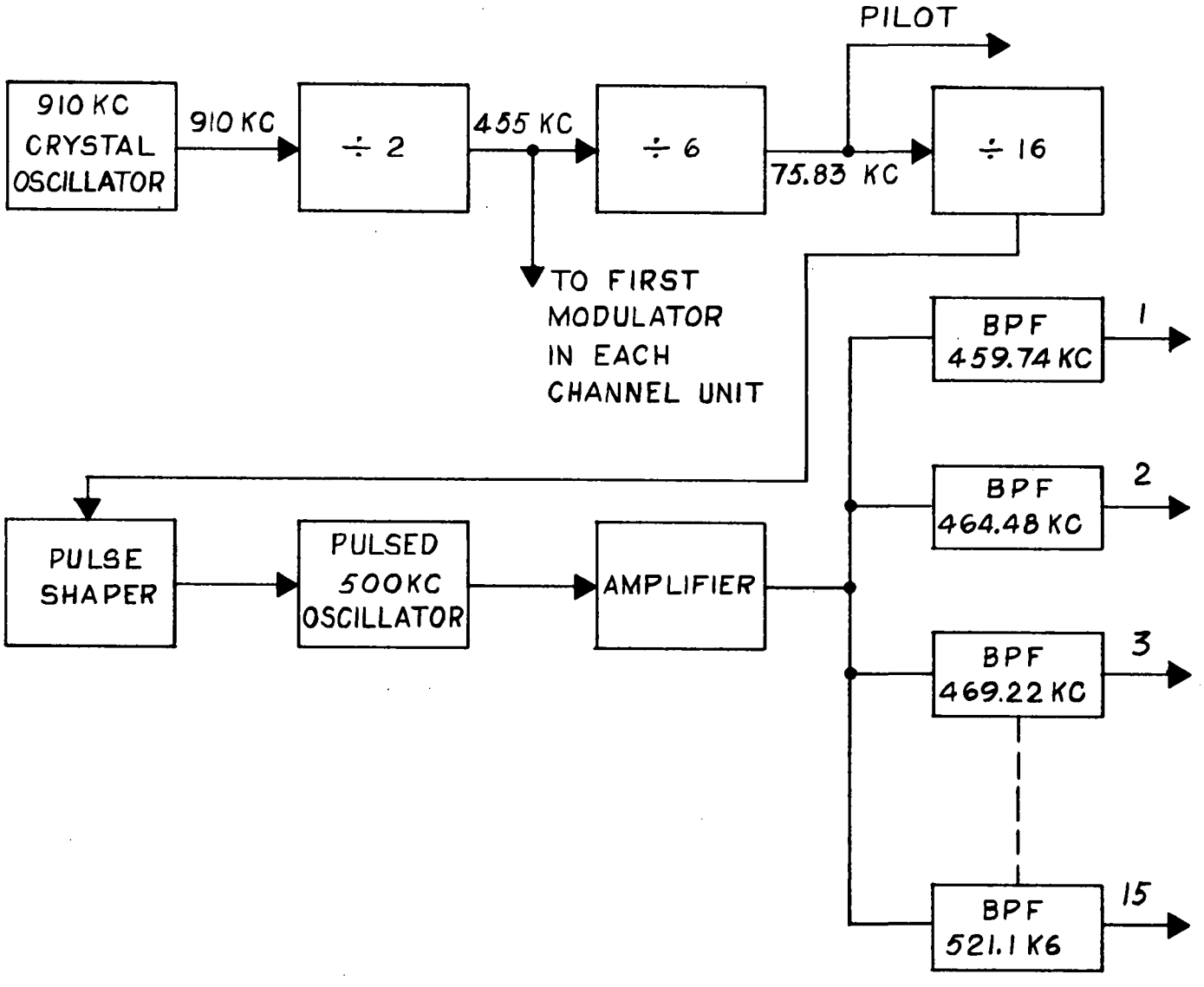

Fig. 2-7 Block Diagram, SS-FM Common Equipment

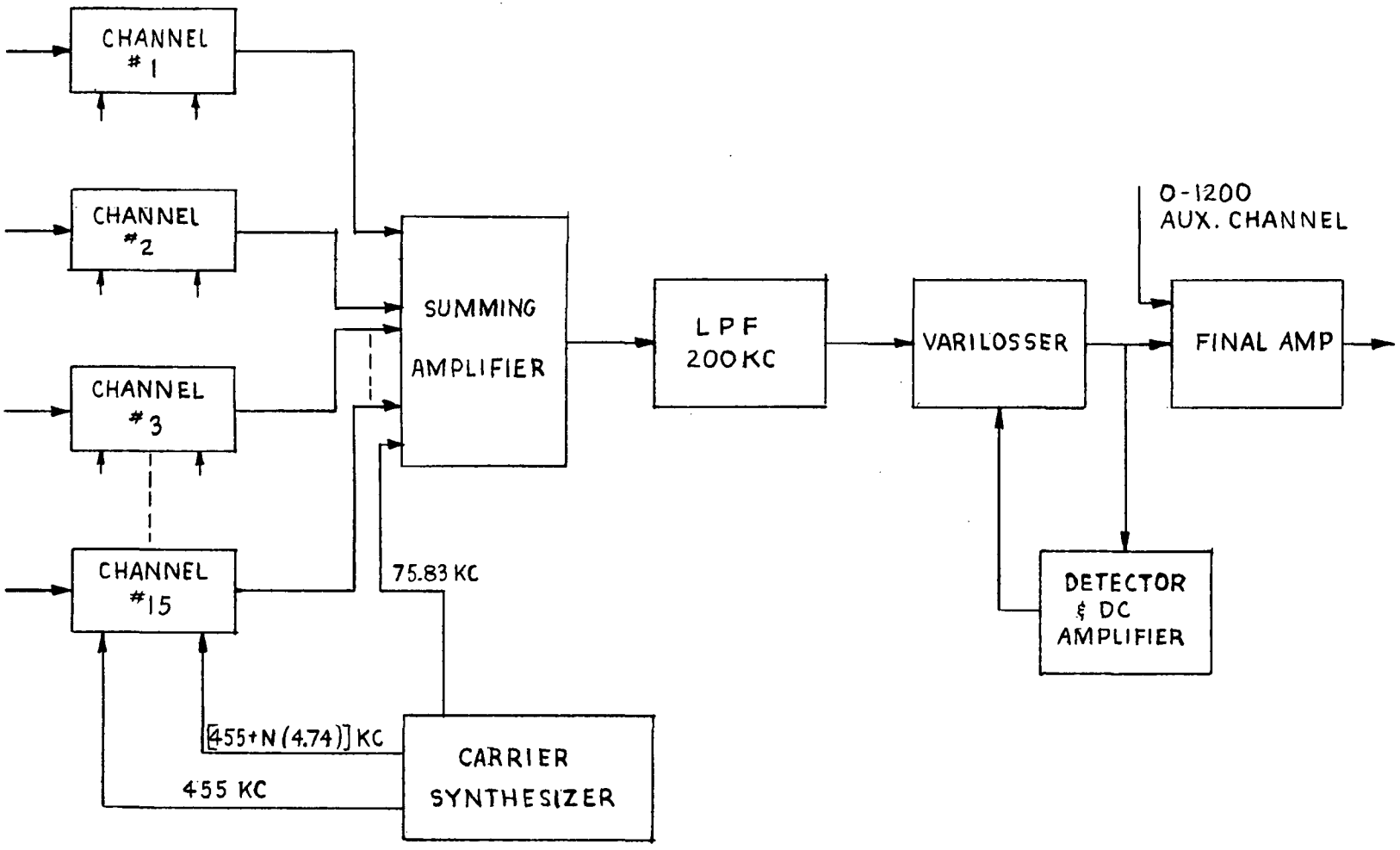

Fig. 2-8 Block Diagram, SS-FM Multiplexer System

2.1.2.2 Advantage of Present Equipment

One advantage of the present equipment design is the complete interchangeability of channel units. This reduces cost by reducing parts and spare parts inventory and by simplifying maintenance. The use of one oscillator to control both the vehicle and ground equipment simplifies circuitry problems. The use of AGC before the FM carrier modulation provides an improved signal-to-noise ratio at low signal levels by keeping the FM carrier deviation high.

2.1.2.3 Disadvantages of Present Equipment

The main disadvantage of presently available equipment is the loss of low frequency response due to the passband characteristics of the mechanical filter employed in generating the single-sideband signal. This means that a PCM or PAM channel must be utilized for vibration data below 50 cps. A bandwidth saving would result if this problem were overcome. Another difficulty lies in the varilosser. This is a diode bridge circuit which requires careful balancing of the diodes, thus adding cost to the final product.

2.1.2.4 Physical Description

The SS-FM multiplexer dimensions are 10 by 10 by 9 inches, and it weighs approximately 15 pounds. It requires +18 and +21 volts which are derived from voltage regulators on the +28 volt bus.

2.1.2.5 SS-FM System Application

In order to provide the required 10 channels of 2000 cps vibration data handling capability plus other low-frequency data handling capabilities (there is a shortage of 0.5 cps channels) on one SS-FM link, an SS-FM multiplexer will be needed. Channels 1 through 5 will be PAM submultiplexed to provide 130 channels for 0 to 12 cps data plus two sync channels and two calibrate channels. The remaining 10 channels will carry the 50 to 2000 cps vibration data. The 0 to 50 cps portions of the vibration measurements will be carried by the PAM-FM-FM links. The system is shown in Fig. 2-9.

2.1.3 PCM-FM Data Acquisition System

It is the understanding of LMSC that this system will be GFE and that it is currently in the design and development process with prototype evaluation scheduled to start during the month of October. LMSC will follow the progress and results of these tests as closely as possible in order to develop an appreciation for the application of this data acquisition system to the RIFT program.

Efforts are currently under way to establish the type, number, and location of the minimum data inputs necessary for adequate checkout of the vehicle. This listing will be useful in the event that redundant telemetry of the main diagnostic data is not planned.

Considerable coordination with MSFC is planned in order to define this system and its implementation thoroughly.

A block diagram of the system is shown in Fig. 2-10.

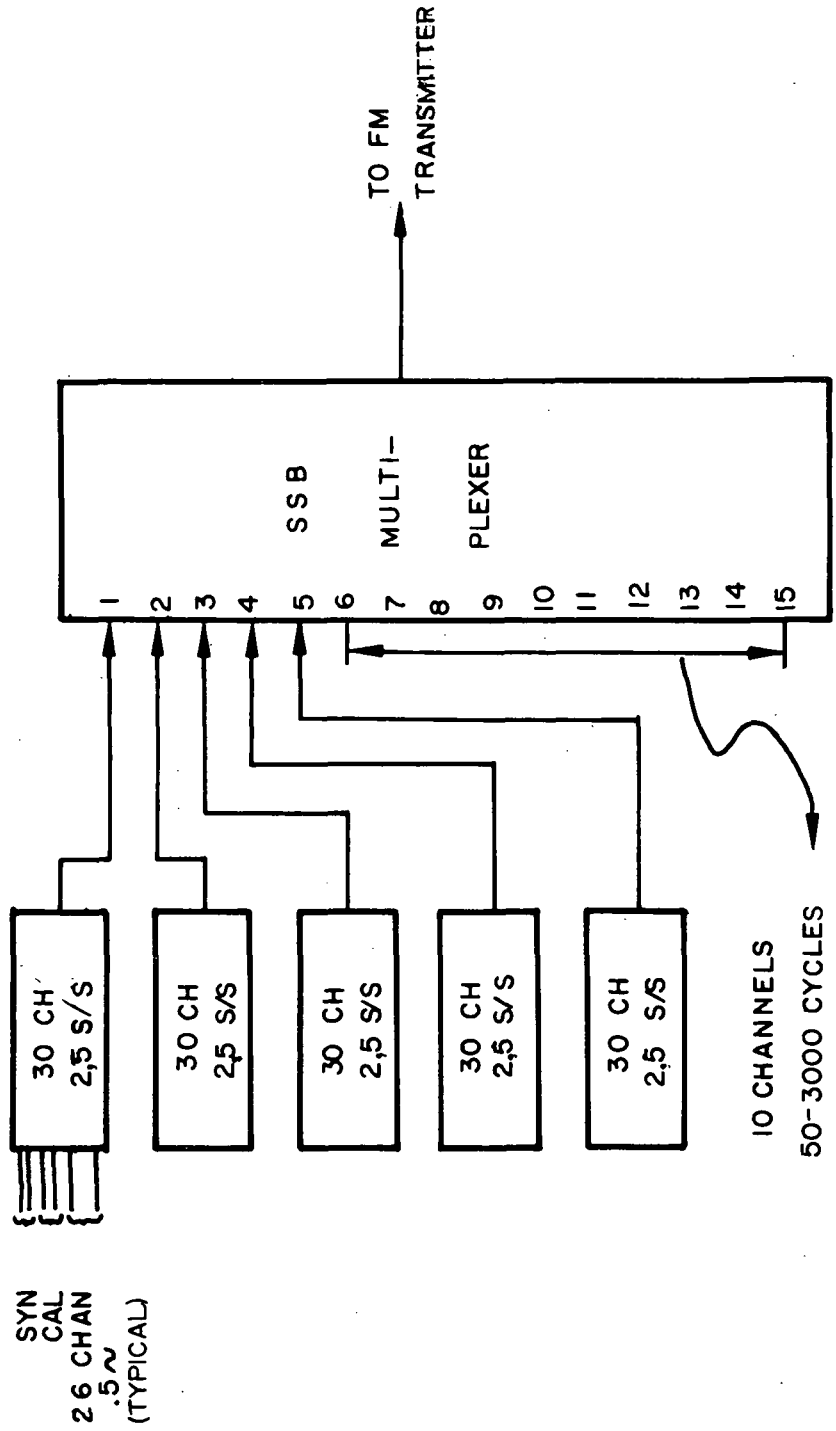

Fig. 2-9 Block Diagram, SS-FM System

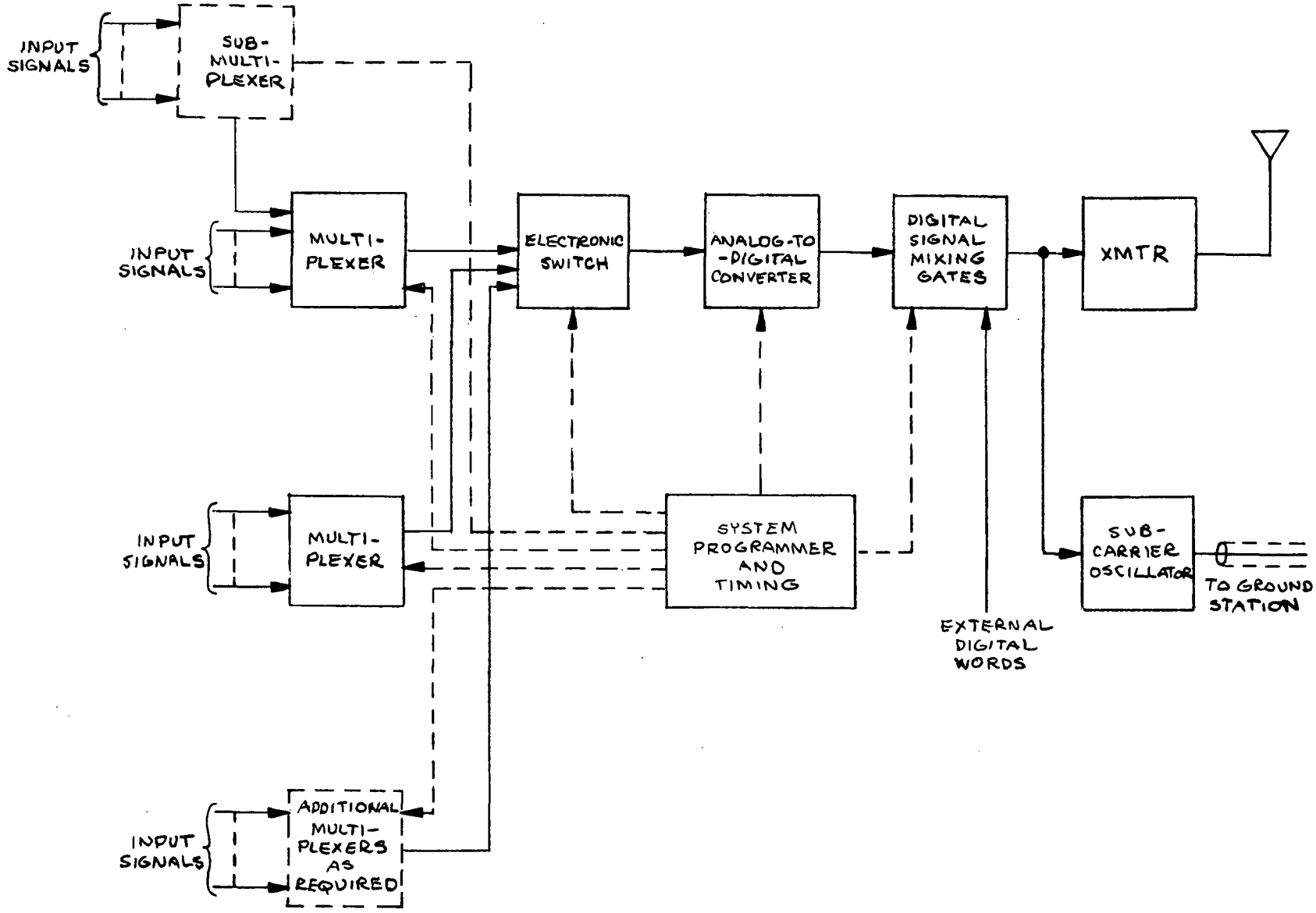

Fig. 2-10 PCM-FM Data Acquisition System

2.1.4 Airborne Magnetic Tape Recorder

Preliminary propagation studies indicate that the plasma sheath created by engine by-products may severely affect (and even interrupt) communications in the VHF region during engine start-up and operation (refer to Para. 2.4). In view of this, the inclusion of one or more airborne magnetic recorders in the telemetry system is being considered. These recorders will be programmed by the inflight sequencer to read-in or playback, with alternate real-time commands available for backup control. Read-in will commence as engine thrust is increased from 1 to 100 percent and will continue until cutoff is commanded. At this time, playback will commence. On Flight 2, read-in/playback will be at an 18:1 ratio; on Flight 3, 4:1;and on Flight 4, 2:1. The transmitters for the SS/FM (vibration) and PCM/FM (Automatic Checkout) links are being considered as possible links for transmitting the data during playback.

Several operational concepts are being considered in the design, such as:

- Wideband recording of the output of the modulation buses of several of the PAM/FM/FM links
- Selective recording of filtered bands of the modulation buses, with playback at ratios of 4:1 or 18:1
- Digital recording of the PAM data from selected portions of the multiplexers

These techniques have all been utilized successfully on AGENA flights during various USAF test programs. The equipment is readily available from sources such as Ampex, Speidel, PIC or LMSC.

2.2 TRANSMITTERS

Considering the large number (13) of VHF telemetering links required to satisfy the RIFT data requirements, tri-helix ground antenna gains must be used in calculating transmitter power required. AMR currently has only two TLM-18 antennas, each capable of handling only 8 receivers. Table 2-2 is the computation of required transmitter power. The minimum power required is 20 watts. Using the available LMSC TMR-3 transmitter with a rated power of 30 watts, a safety margin of approximately 2 db is available for presently incalculable losses such as radiation and ionization.

2.2.1 The TMR-3 Transmitter

The TMR-3 transmitter provides an output of 30 watts in the frequency range from 225 to 265 mc. The power requirements are:

-500 v at 110 ma

-250 v at 10 ma

+225 v at 60 ma

6.3 v rms at 1.05 a

6.0 v rms at 3.0 a

These requirements are met by its associated power supply. The modulation signal requirements are 0 to 5 v p-p into 35,000 ohms which produces a peak deviation of 125 kc.

The transmitter measures 3.375 by 4 by 5 in. and weighs 2.3 pounds.

Table 2-2

RF GAIN CALCULATIONS, RIFT FLIGHTS (1-4) VHF (FM) - TRI-HELIX ANTENNA

Carrier frequency	235 mcs
Range	700 nm
I-F bandwidth	300 kc
Output signal-to-noise required	27 db
Transmitter power (1 watt)	0 dbw
Xmtr line and multiplexing loss	-2 db
Antenna gain (conservative)	-5 db
Misc. losses (aging, etc.)	-2 db
Space attenuation	-142.0 db
Fading and polarization (conservative)	-9 db
Receiving antenna gain (tri-helix)	16 db
Antenna misorientation	-1 db
Receiver line filter losses	-2 db
Input power available to receiver	-147 dbw
Output S/N required	27 db
Practical receiver aspects	9 db
Threshold required	12 db
Modulation NIF	7 db
RMS noise power ($K T_E B_{IF}$)	-140 dbw
Receiver threshold including 3 db safety factor	15 db
Input power to receiver with respect to 1 watt	-147 dbw
Required transmitter power	13 dbw (19.97 watt)
Transmitter power recommended	30 watts

2.3 ANTENNA DESIGN

The RIFT vehicle requires three antenna systems: tracking, telemetry, and command/destruct. This section will discuss the conceptual design of these antenna systems.

2.3.1 Tracking Antennas

2.3.1.1 C-Band Beacon

This antenna will consist of a short monopole recessed into a circular flush mounted cavity approximately three inches in diameter and one inch deep. It will be located on the Z axis. The polarization will be perpendicular to the yaw plane of the vehicle. The radiation pattern will be omnidirectional in all planes parallel to the yaw plane. It will have the typical pattern of a quarter wave vertical monopole above a conducting ground in pitch and roll. This pattern is plotted in Fig. 2-11. Fig. 2-12 shows the antenna.

2.3.1.2 Azusa/Mistram

A conventional Azusa C-band tracking antenna similar to that used on the Polaris vehicle will be provided. This antenna will have a pattern that will provide adequate horizon-to-horizon coverage to maximum range during the ballistic flights of the RIFT vehicle. This coverage is very similar to that of a vehicle in orbit at an altitude of 280 nautical miles in a horizontal altitude. This antenna will not necessarily be omnidirectional since, in the event of loss of vehicle stabilization, radar skin track and telemetry angle track can provide sufficient trajectory data. Information is not presently available as to the X-band Mistram antenna. Studies of this and all other antenna designs are being conducted by the LMSC Research Microwave Systems Laboratory.

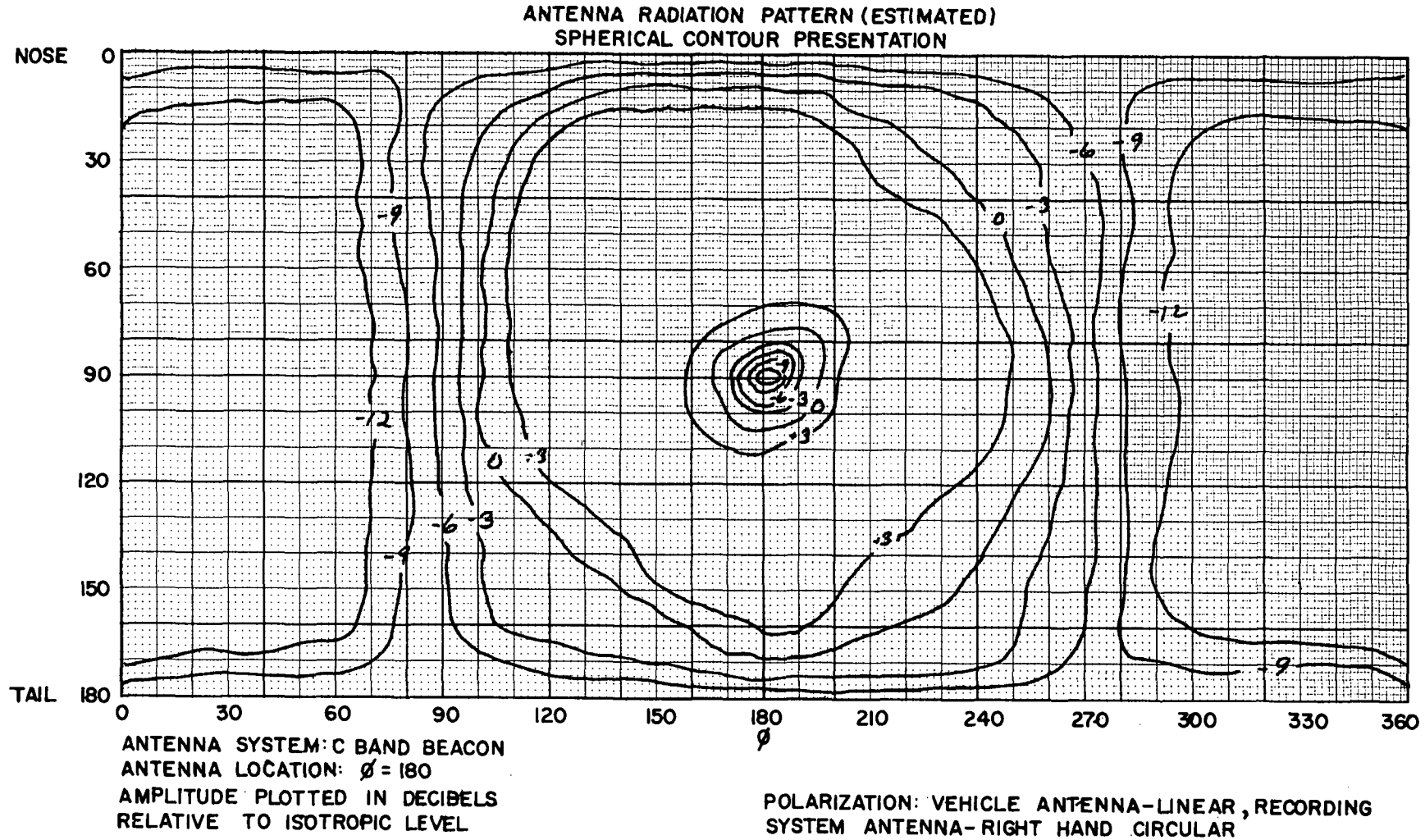

Fig. 2-11 Radiation Pattern, C-Band Antenna

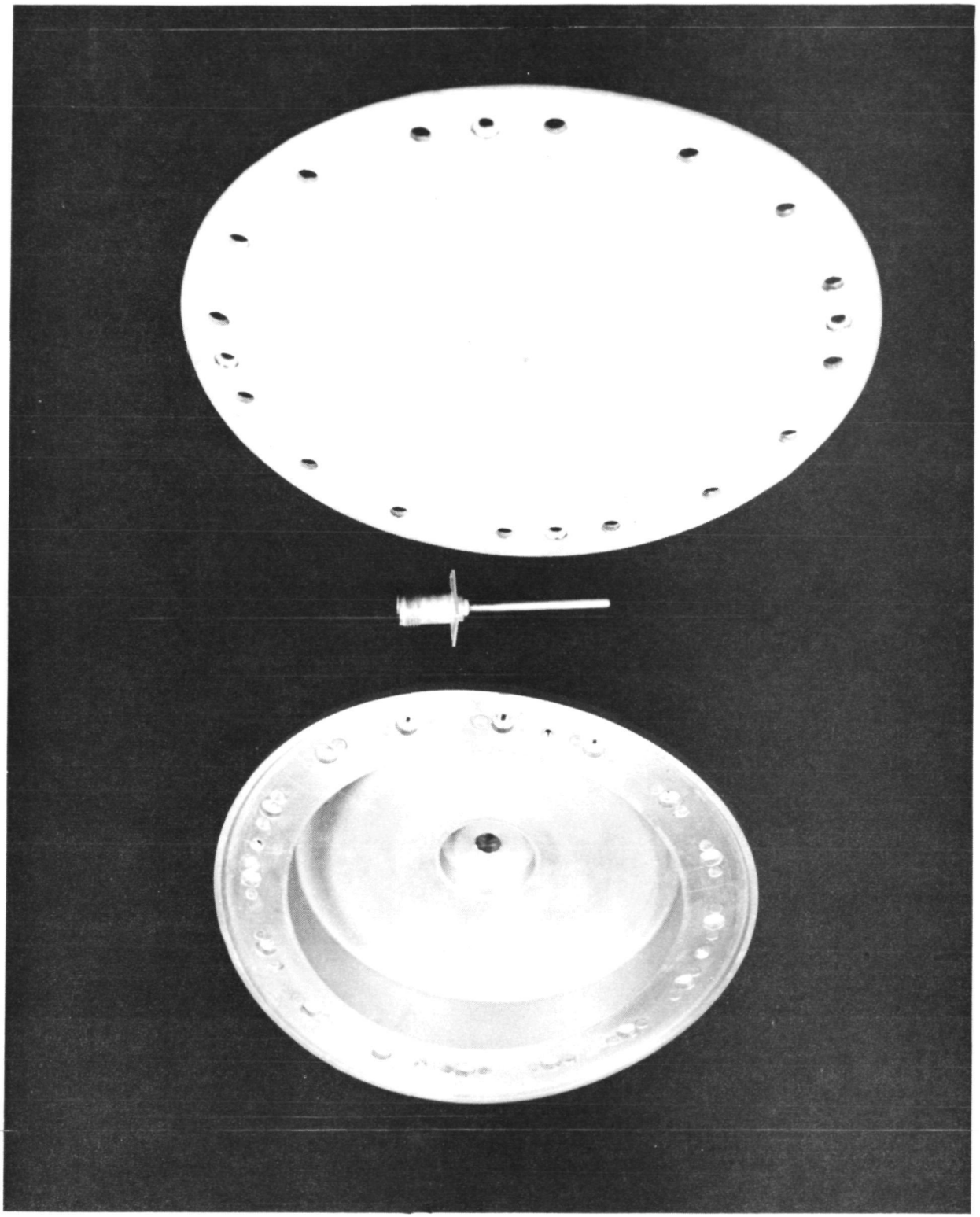

Fig. 2-12 C-Band Antenna

2.3.2 Telemetry Antenna

2.3.2.1 VHF Telemetry

For the thirteen VHF channels required, it is proposed that three separate cavity-backed slot antennas be used. Two of these will transmit five channels each, while the third will be used for three channels and have sufficient bandwidth to provide two spare channels. It is considered that multicoupling five links to one antenna will be satisfactory. Channels adjacent in frequency (nominal 4-Mc separation) will be used with each antenna to minimize bandwidth requirements. Studies will be continued on the multicoupling design and its reliability. The antenna will be approximately 22 in. long by 6 in. wide and 6 in. deep. Pattern coverage for each antenna will be approximately as shown in Fig. 2-13. A circularly polarized ground antenna is assumed and the contour levels plotted can be used directly in the link calculation.

2.3.2.2 UHF Telemetry

Considering the crowded VHF spectrum (215-260 Mc), it is possible that direction may be given to utilize the upper UHF spectrum (2200-2300 Mc) for the RIFT and operational vehicle telemetry. A proposed antenna system design for this region is as follows. The antenna pattern is shown in Fig. 2-14. This system will consist of an array of five crossed-slot antennas with the center of the array on the +Z axis. Each antenna will be two crossed $\lambda_o/2$ slots backed by a waveguide cavity 10 in. long by 4½ in. wide by 2.3 in. deep. In addition to the antennas there will be a stripline feed network to provide the necessary phase

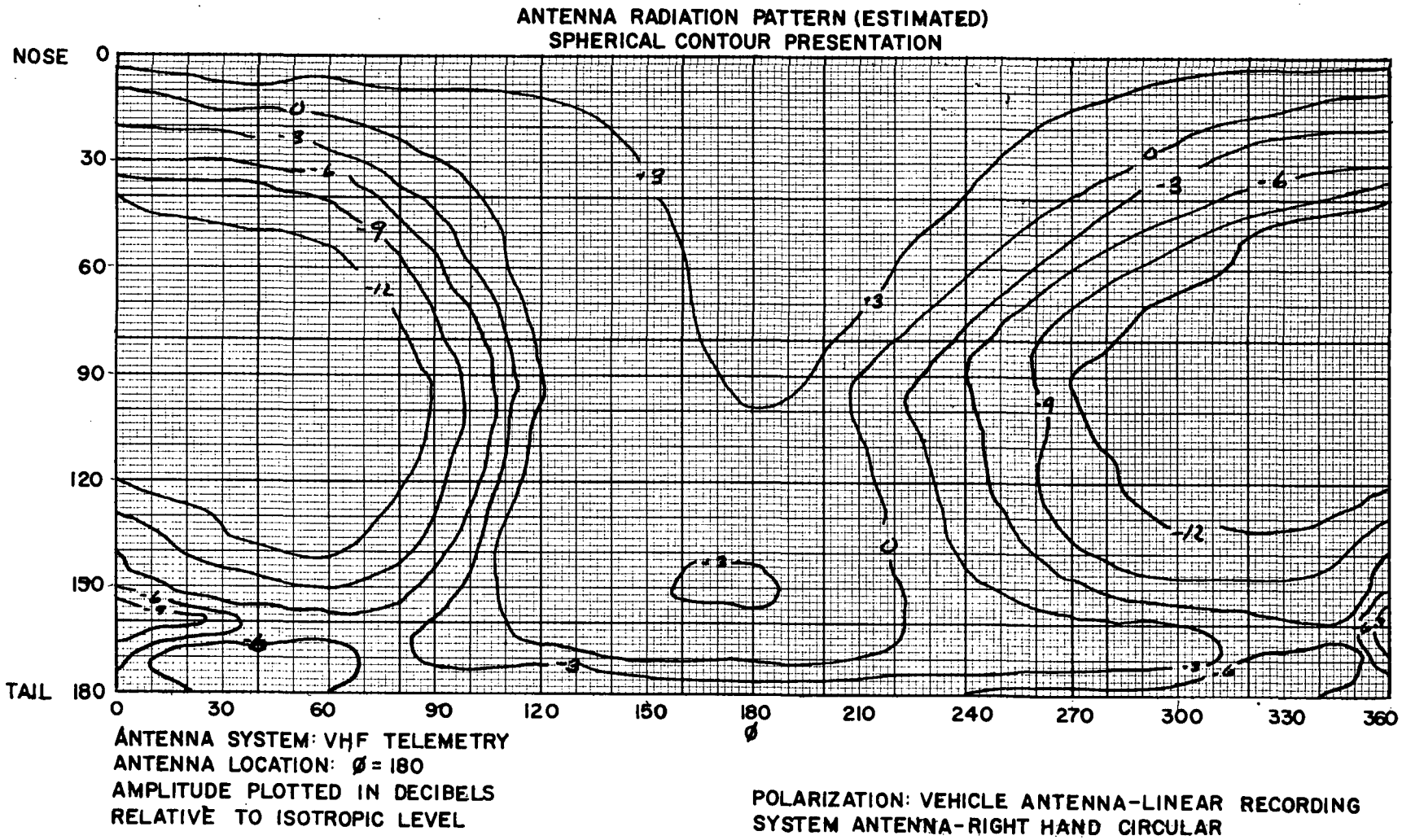

Fig. 2-13 Radiation Pattern, VHF Antenna

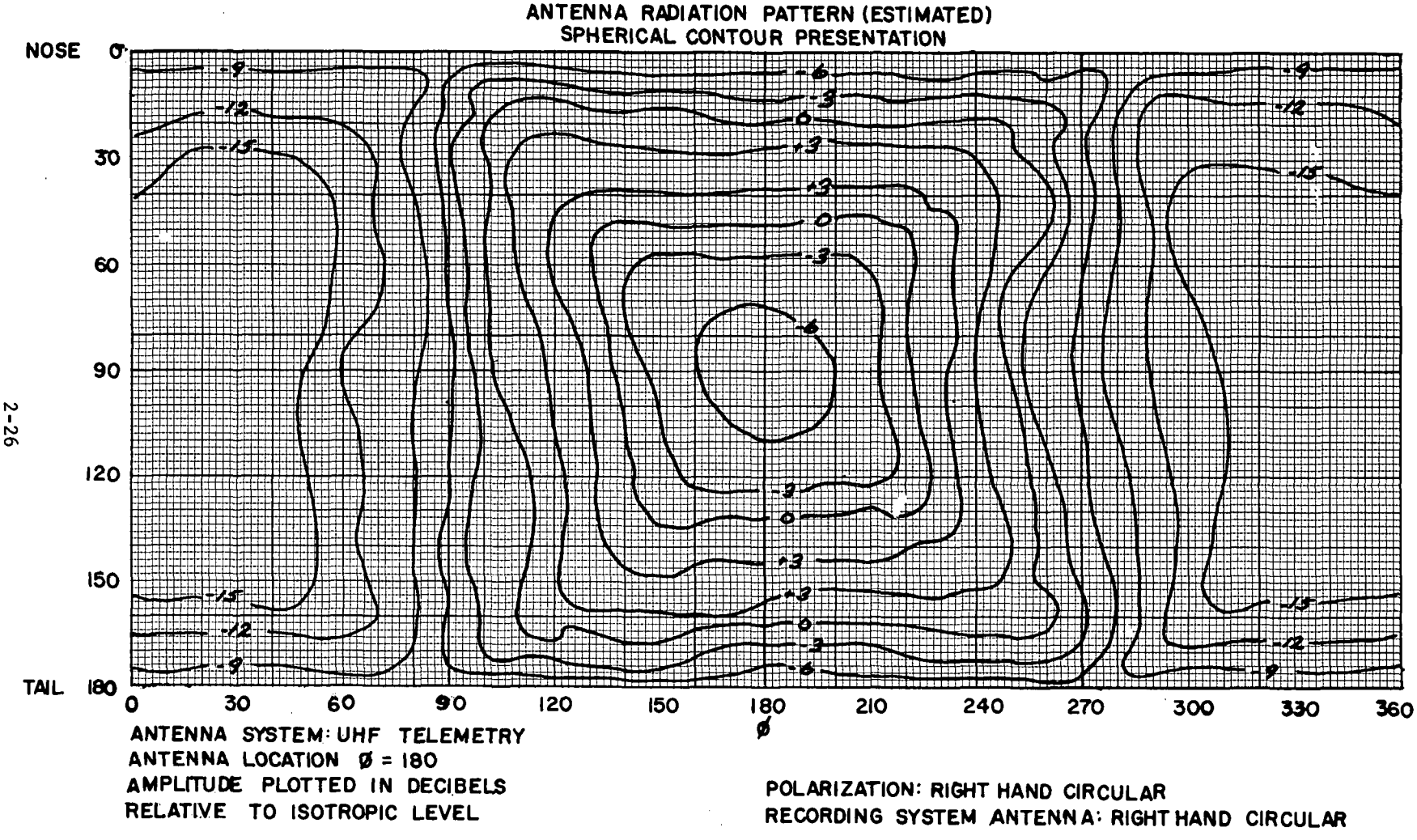

Fig. 2-14 Radiation Pattern, UHF Antenna

and amplitude distribution to the array. The antenna polarization will vary from right hand circular on the axis of the antenna to agree with the polarization of the ground antennas, to elliptical everywhere else in the area of interest. The radiation pattern will be close to omnidirectional in all planes parallel to the yaw plane. It will have a pattern similar to that of a quarter-wave vertical monopole above a conducting ground in pitch and roll. The pattern will display a maximum gain of 4 db above isotropic at an angle of 30 deg from the yaw plane and a minimum gain of 8 db below isotropic looking directly into the antenna. There will be no severe polarization null with this antenna.

2.3.3 Command/Destruct Antennas

The command/destruct antenna system consists of two cavity-backed E-slot antennas located 180 deg apart on the vehicle circumference. The antennas are connected to two redundant receivers through a hybrid. The response of either receiver in this system is shown in contour form in Fig. 2-15.

It is a requirement of AFMTC range safety that 95 percent of the power radiation sphere be above a level which is 12 db above system threshold. Approximately 95 percent of the radiation sphere of the pattern associated with this system may be expected to be above a level of 12 db referenced to isotropic.

Each cavity will be 7 in. long, 9 in. wide and 2 in. deep. The main antenna polarizations will be linear horizontal during the operating period. However, there will be a relatively large cross-polarized signal which, in conjunction

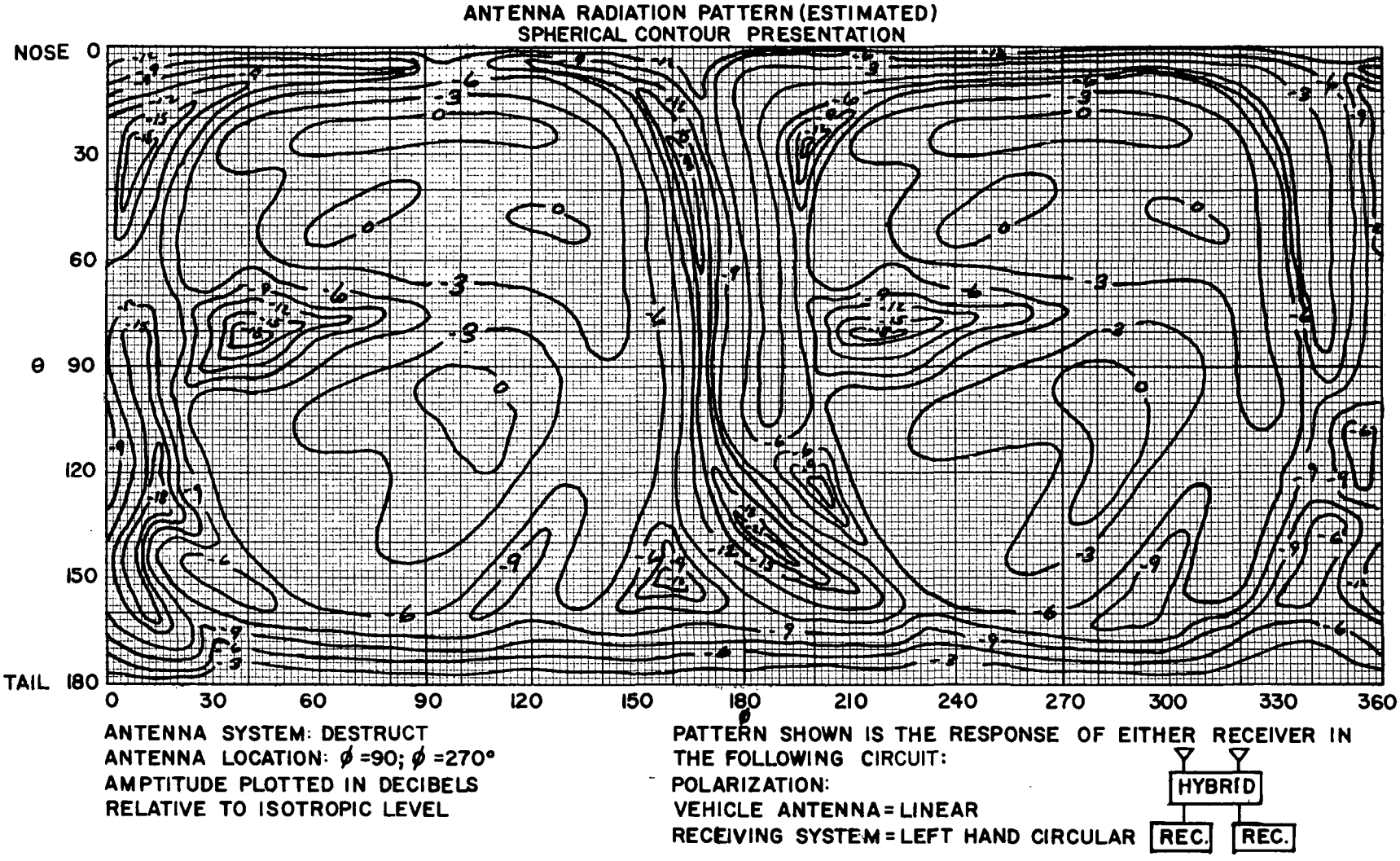

Fig. 2-15 Radiation Pattern, Command/Destruct Antenna

with the main polarized signal and a circularly polarized groove antenna, will provide a composite pattern which approaches omnidirectional characteristics for the referenced gain level. Figure 2-16 shows a typical cavity backed E-slot antenna of this design.

2.4 ELECTROMAGNETIC INTERFERENCE

The interference produced by electrical, mechanical or nuclear systems in the RIFT vehicle must be controlled to prevent undesired interaction, malfunction or degradation of any subsystem within the vehicle.

An Interference Control Plan will be submitted which will describe the interference control program and the engineering design procedures and techniques that will be used to comply with the various military and Lockheed EMI specifications.

In general, the areas which will be covered are conducted and radiated interference and susceptibility testing. All efforts will be taken to insure that the design of the electrical and electronic systems will be such that, before interference control components are applied, the inherent interference generated will be minimal.

The nuclear environment contributes to the interference problem in that as certain components are irradiated they degrade. Semiconductors are particularly sensitive to radiation, and their degradation will tend to increase the noise level of the system. Preliminary investigations, however, indicate that the

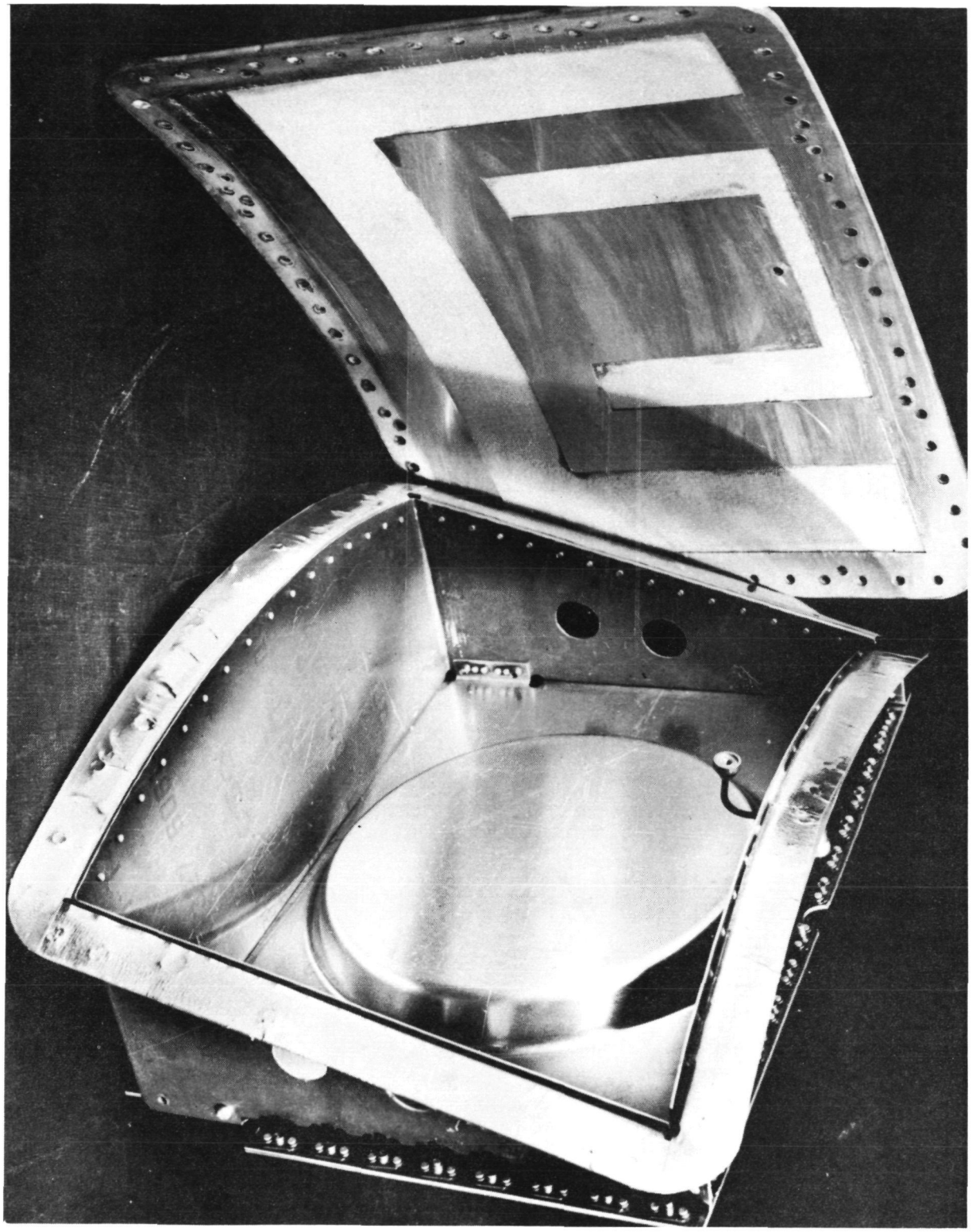

Fig. 2-16 Cavity-Backed E-Slot Destruct Antenna

radiation levels in the equipment section will not be greater than 10^{11} n/cm^2/sec. neutron flux or 10^5 r of gamma. These limits are considered to be acceptable and should have little effect on the operating characteristics of the various systems if reasonable care is taken to select components which are less sensitive to a radiation environment, and if good design techniques are used.

Radio propagation problems are also being investigated as a part of the interference problem. Neutron, gamma, beta, and x-ray ionization of the exhaust gases can cause signal attenuation. Preliminary studies indicate that at RIFT startup, the gamma-induced atmospheric ionization could cause as much as 20 db signal attenuation of 225 mc transmissions on a path parallel to and 30 meters from the flight line. At altitudes above 50 miles, signal attenuation would be appreciably reduced. Additional investigations in this and other related areas are continuing.

2.5 VEHICLE-BORNE TRACKING AIDS

The following tracking system requirements are being considered for the RIFT program:

- Ascent tracking to support ground control
- Ascent tracking to support range safety
- Tracking to provide data to assist in post-flight analysis of vehicle, engine, and guidance system performance from lift-off through RIFT S-N Stage splash

Additional requirements being considered for the operational vehicle program include:

- Escape trajectory tracking
- Orbital tracking

The tracking systems under consideration are AZUSA, C-Band Beacon, and MISTRAM. Separate vehicle antennas will be provided for each tracking system. Table 2-3 shows comparative information on the three systems.

Table 2-3

TRANSPONDER COMPARISON

Transponder	Frequency	RF Power	Weight	Power Req'd	Accuracies	
					Range	Range Rate
AZUSA MK-II Type B-2	5000 Mc	5 w	36 lb	330 w	5 ft*	0.1 fps
AN/DPN-71 (Motorola)	5395-5905 Mc	24 kw Pulsed	25 lb	150 w	Max ±50'* Systematic ±10' random	Not reduced
SST-102A (Motorola)	5400-5900 Mc	500 w (min)	10.8 lb	45 w	"	—
MISTRAM (G.E.)	8148-8216 Mc	500 Mw (min) per chan.	16.4 lb	170 w	0.4 ft	0.03 fps

*Based on flight test data.

2.5.1 AZUSA

For the RIFT vehicle the AZUSA M-II is capable of providing all required tracking data. This is a flight-proven, consistently accurate tracking system. Reduced test data has demonstrated accuracies as follows:

Space position (x,y,z)	5 ft
Velocity ($\dot{x},\dot{y},\dot{z}$)	0.1 ft/sec

For operational flights, the AZUSA will probably be replaced by a system with greater range capability such as MISTRAM.

2.5.2 FPS16/C-Band Beacon

For back-up tracking, a C-band beacons such as the AN/DPN-71 or Motorola SST-102A transponders will be installed. The AN/DPN-71 is particularly desirable due to its ruggedized construction, high power output (24 kw) and reliable components.

2.5.3 MISTRAM

The basic tracking system will be supplemented with the MISTRAM system being developed by General Electric for the Atlantic Missile Range. Quoted accuracies of MISTRAM are:

Range	0.40 ft (20 cps)
Range Rate	0.02 ft/sec

Present configuration calls for range coverage from 20 to 1000 nautical miles. With reduced accuracy, ranges considerably in excess of 1000 miles can be handled

with system capability extended to 25,000 miles. With increased power and antenna gain, trans-lunar ranges can be handled. The primary purpose of using the MISTRAM system during RIFT flights will be to evaluate its performance for subsequent operational vehicle flights.

2.6 COMMAND/DESTRUCT SYSTEM

The Command/Destruct System for the RIFT vehicle basically consists of two redundant receiver/decoder units and a command control decoder. Each receiver will include three decoder channels tuned to the appropriate AFMTC coder channel frequencies for destruct purposes. The two redundant systems will have no common items except the antennas, the destructor, and direct connections to these components. They will be individually powered by separate batteries. These characteristics satisfy AMR Range Safety requirements for airborne flight termination systems as stated in AFMTC REG 80-7.

In addition to this standard destruct function, the Command/Destruct System for the RIFT vehicle will have the capability of accepting additional command functions Table 2-4 shows several possible real-time commands which would fall within the capability of the proposed AFMTC Digital Command Control Coder-Decoder. The requirements for this command system are described in Technical Exhibit RE/9452-850

The modulation or coding method will be compatible with the existing ground-based Radio Command Control Transmitter (AN/FRW-2). A typical phase shift keying (PSK) method is shown in Fig. 2-17. The composite modulating signal consists of a 2-kc PSK subcarrier, controlled with PCM inputs, and a 1-kc bit syncronization tone

Table 2-4

COMMAND FUNCTION LIST

Real-Time Command No.	Function
1	Enable engine start or restart
2	Initiate engine start (0-1% power) backup
3	Initiate engine start (1-100% power) backup
4	Engine start override
5	Engine shutdown
6	Engine shutdown override
7	Reset coast period
8	Reset X velocity to be gained (V_{gx})
9	Reset Y velocity to be gained (V_{gy})
10	Reset Z velocity to be gained (V_{gz})
11	Azimuth alignment correction
12	Vertical alignment correction
13	Backup start sequence timer
14	Backup brake sequence timer
15	Airborne tape recorder read-in backup
16	Airborne tape recorder read-out backup

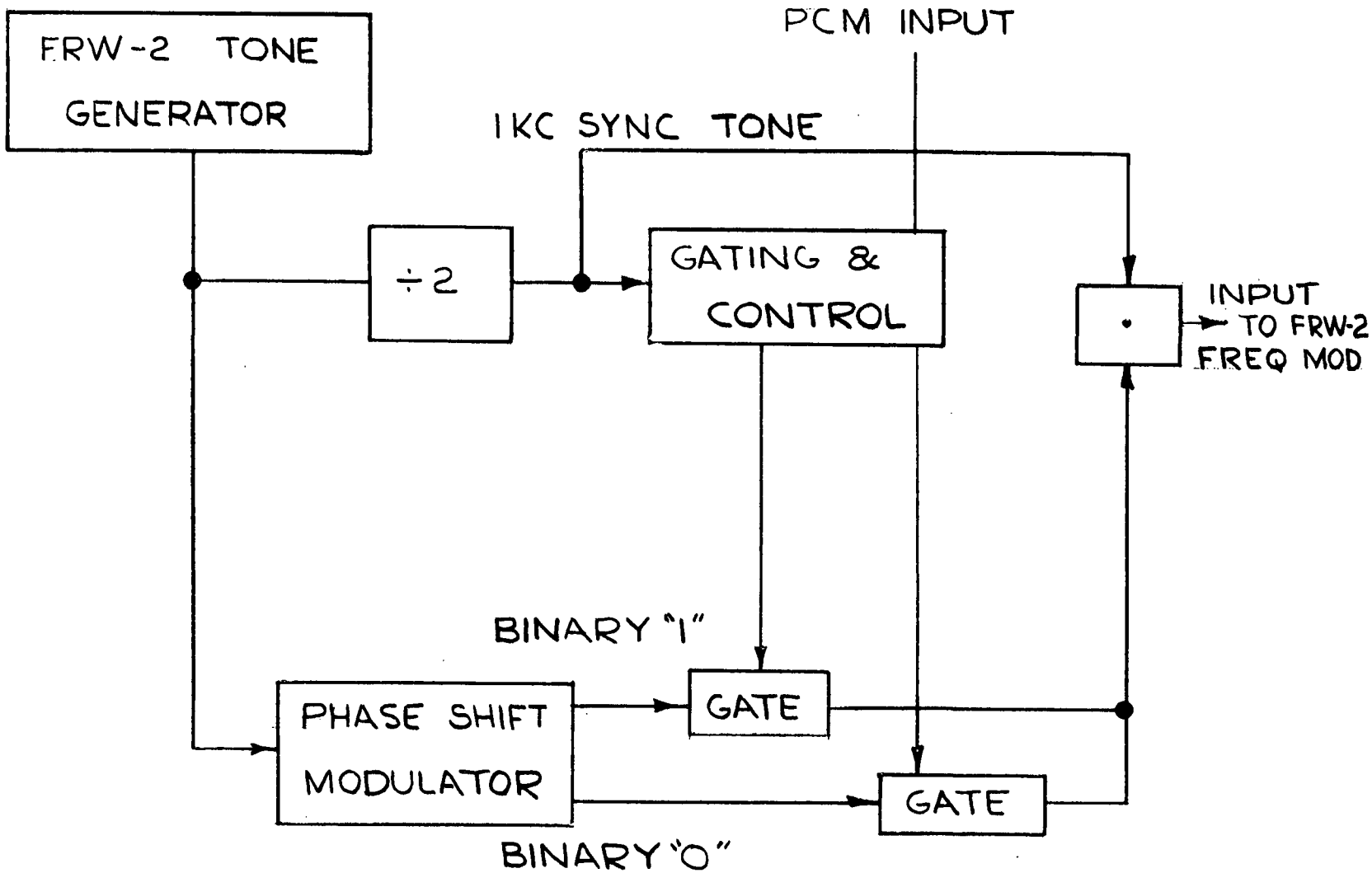

Fig. 2-17 Block Diagram, Ground Modulator

2.6.1 Receiver

The modified Radio Receiver AN/DRW-13 will be capable of receiving the frequency-modulated carrier containing as many as three simultaneous audio tones with r-f bandwidths as great as 750 kc and frequency deviations up to 300 kc.

2.6.2 Decoder

The outputs of both receivers may be combined linearly without switching and fed into a single airborne decoder which consists of a phase shift detector and a data decoder as shown in Fig. 2-18. An alternate method would be to feed the receiver outputs into separate detector-decoders and include decision and switching circuits which would allow only one receiver to complete the command.

The detector provides synchronization pulses and the information pulses from the two tone signals from the receiver. The output of the detector consists of a pulse indicating a data "1", and the absence of a pulse indicating a data "0". This signal is shifted serially into the shift register where message validity checks are made; these include address and parity checks. Upon receipt of a "correct" message an acceptance pulse is generated for transmission to the ground via telemetry. This pulse is also used to gate the label portion of the message through the decoding matrix to provide an on-off function on 1 of 32 output lines. An "incorrect" message will not result in the generation of an acceptance pulse; hence, neither the label information nor the on-off bit is gated to the output. Transmission of a subsequent message will then clear the previous incorrect message which remained in the input register.

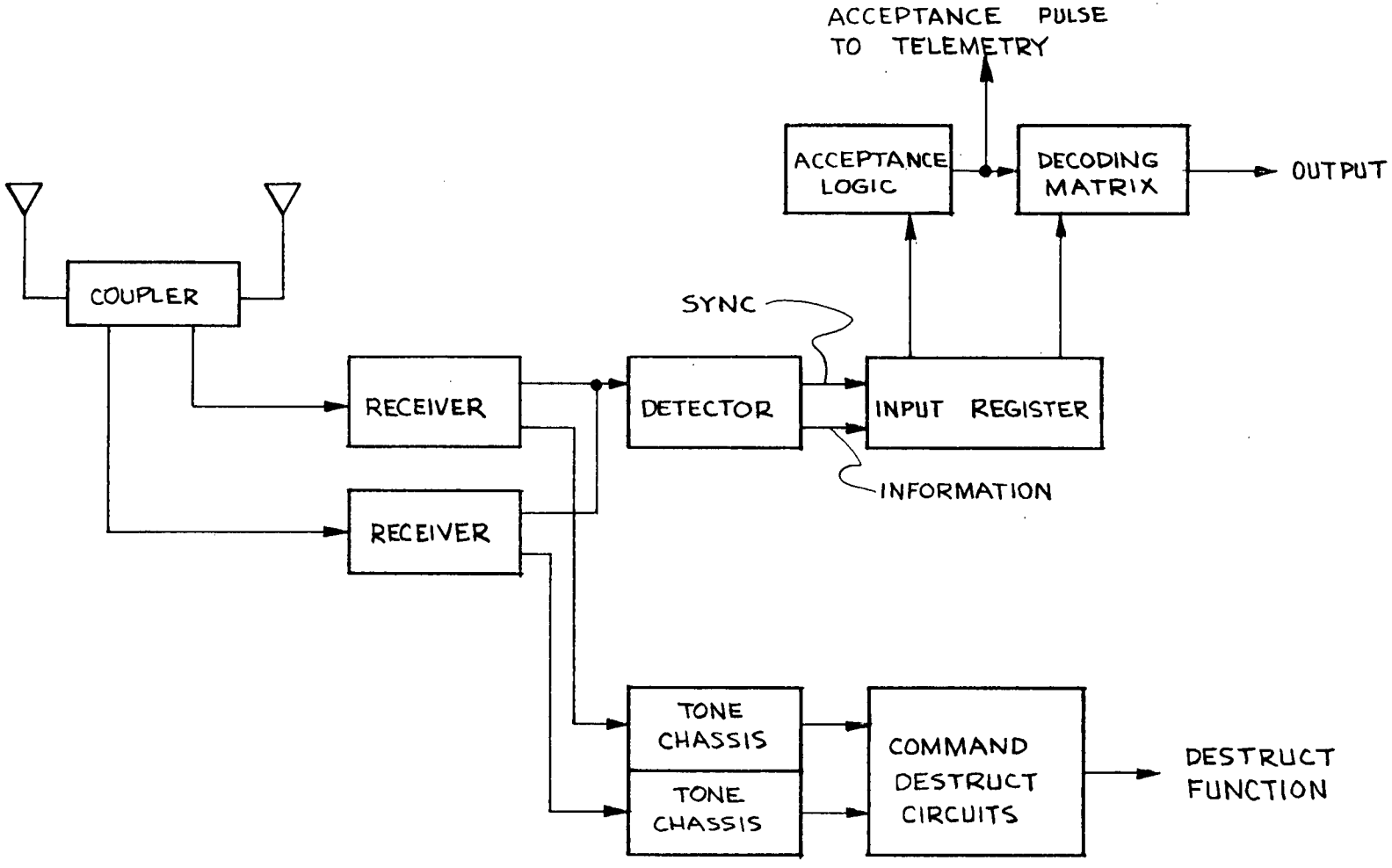

Fig. 2-18 Block Diagram, Command/Destruct System

Message length is largely dependent on the number of possible addresses required. Present planning indicates that a 3-bit address which provides 8 possible addresses selectable by patch wiring would be adequate.

The remainder of the 10-bit message consists of 1 parity bit, 5 label bits and 1 on-off function bit. To decrease the possibility of accepting a false command, the message length could be increased by providing: (1) additional parity checks on several portions of the message, (2) additional address bits, and (3) inclusion of message length checks. This decrease in vulnerability to false commands is accompanied by an increase of hardware and, hence, a decrease in reliability. Therefore, the simpler system with a 10-bit message length was chosen.

2.6.3 Command/Destruct Power

Each command destruct receiver decoder and exploding bridgewire firing unit will be powered from a separate silver-zinc battery. The capacity of these batteries is 35 w-hr at a maximum discharge current of 10 amps.

2.7 HARDENING AND SHIELDING

The system effect resulting from combining the radiation environment of the RIFT vehicle with the standard environments (vibration, temperature, shock, acceleration, etc.) cannot be predicted simply by adding the effect produced by the separate environments. Lockheed is presently engaged in test programs which will give combined environmental effect prediction data. Included in these programs are the LNP Radiation Effects Program, the RIFT Cryogenic Test Program, and the USAF-sponsored SNAP radiation effects tests. In the design phase, emphasis will be

placed on the use of components and parts which have been successfully tested in an environment similar to that of the RIFT flight tests. When design information is not available, test or analytical studies will be conducted in an effort to determine the capability of the unknown component or part to withstand the environment.

It is anticipated that some areas may not be sufficiently hardened to withstand the nuclear or temperature environment. These cases will be taken separately as they arise, and proven nuclear or temperature shields will be recommended and become a part of the design. As components are improved, or if ground test data indicates that shielding is not necessary, it will be removed. All attempts will be made to keep the amount of shielding to a minimum and still maintain a high degree of reliability.

Section 3

ELECTRICAL SYSTEMS

The electrical subsystems employed in the S-N Stage (Fig. 3-1) are: (1) power supplies and power distribution subsystem, (2) nuclear engine control subsystem, (3) measurement and telemetry subsystem, (4) tracking and safety subsystem, (5) command destruct and ordnance subsystem, and (6) sequencing controls. The electrical subsystems are designed for and compatible with the on-board PCM checkout telemetry. The destruct and safety subsystem is to be integrated with the nuclear engine control subsystem and with the guidance and control subsystem as the details of the engine and control subsystem become available.

3.1 PRIMARY AND SECONDARY POWER

The primary source of power for the RIFT vehicle will be four silver-zinc batteries with an energy-to-weight ratio of 80 W-hr/lb. The factors considered in making the selection were the following: (1) capacity-to-weight factor, (2) energy-to-volume factor, (3) internal resistance, (4) voltage variation, (5) surge discharge capability, (6) test and qualification status, and (7) activated life. A comparison between the nickel-cadmium and the silver-zinc systems is shown in Table 3-1.

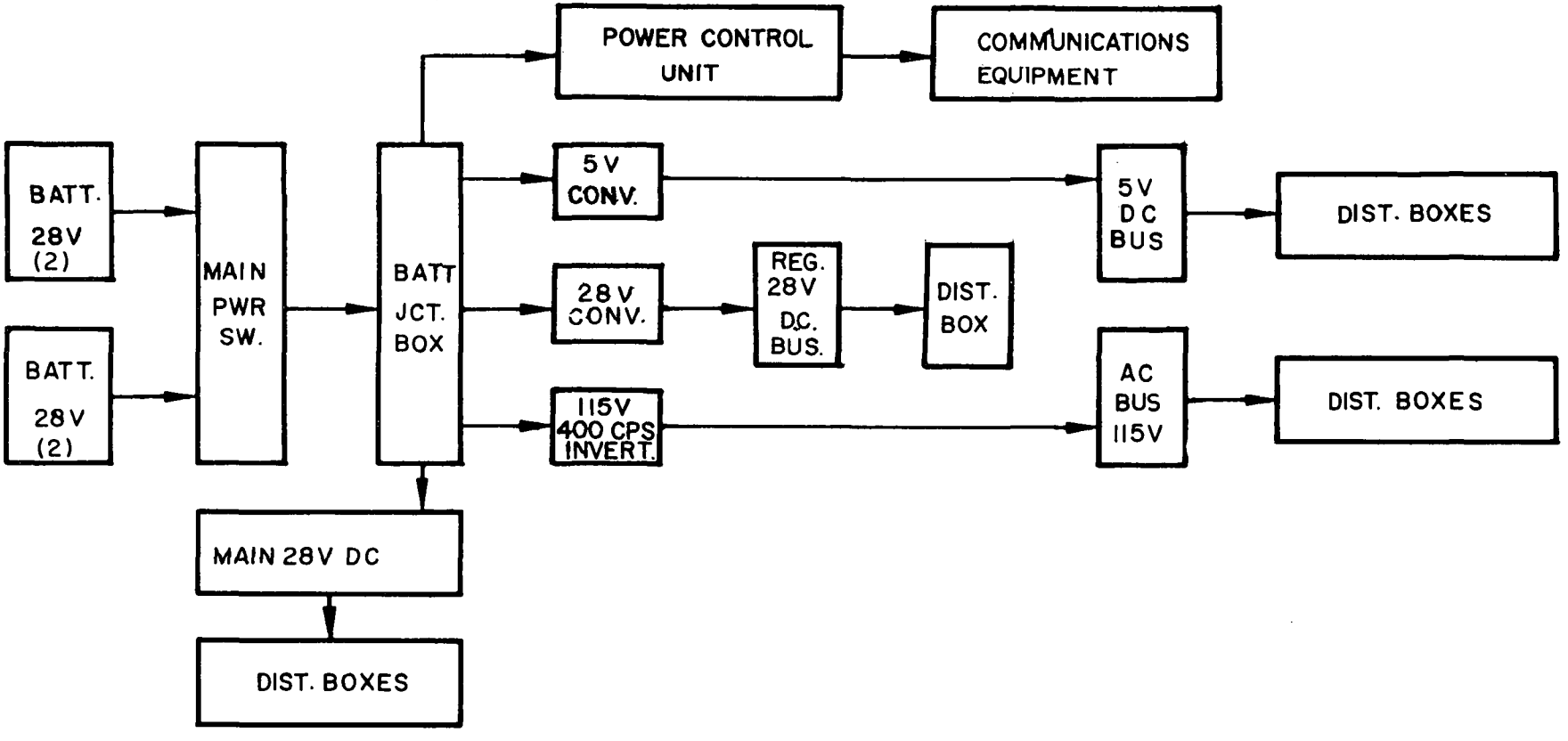

Fig. 3-1 Block Diagram, Electrical Power Systems

Table 3-1

COMPARISON OF NICKEL-CADMIUM AND SILVER-ZINC BATTERIES

Characteristics	Nickel-Cadmium	Silver-Zinc
Energy/Weight	10 w hr/lb	80 w hr/lb
Energy/Volume	10 w hr/in^3	4.2 w hr/in^3
Voltage Variation to 90% Discharge	+8 to -16%	+3 to -10%
Surge Discharge	3000 Amps	1000 Amps
Qualification Status	Qualified	Qualified
Activated Life	90 Days	30 Days at 40°F

It is apparent that the silver-zinc characteristics outweigh the nickel-cadmium except for activated life and surge discharge. The discharge capability of silver-zinc batteries is more than adequate for the RIFT S-N Stage. Even though the weight and space is not a problem at this time, the handling of a large nickel-cadmium battery would prove to be difficult for installation. Since silver-zinc battery units have been flown successfully, this system was chosen for the S-N Stage.

This battery unit will consist of 17 series-connected silver-zinc primary cells with a nominal potential rating of 26.7 volts. The capacity rating is 46 ampere hours at the 5-hour rate. Voltage regulation will be from 22 to 29.25 volts under the environmental and load cycle conditions expected.

The alkaline-electrolyte, silver-zinc battery will be installed in the equipment compartment where the expected radiation level will be 1.4×10^{10} nvt and 3.5×10^{3} r. This level of radiation will not affect the batteries selected since it is below their threshold damage dose by several orders of magnitude. The most sensitive material in this battery will withstand levels between 10^{6} r and 5×10^{6} r.

Battery data are summarized below.

Electro-chemical system	Silver peroxide-zinc alkaline
Capacity	1300 w-hr at 46 amp-hr rate
Voltage limits	+22.0 to +29.25 volts
Number of cells	17
Storage	1 year (unactivated)
Minimum wet stand time	15 days at 80°F
Discharge temperature	40 to 100°F
Safety relief valve	Provided
Weight	26 lbs
Size	12.25 by 6.25 by 5.70 in.
Connector	97-3102c-24-12P
Case finish	MIL-F-7179

3.1.1 DC-DC Converters

3.1.1.1 28-Volt Converter

Certain of the electrical equipments require regulated dc voltage of 28v ±1% and a reference voltage source for the radiation detectors. To provide this type of power, a conversion unit currently employed in the IMSC Space Systems Division has been selected. This unit will be capable of withstanding a radiation environment of 1.4×10^{10} nvt and 3.5×10^{3} r.

The basic requirements for this converter are summarized below.

Input voltage	22 to 29.25 vdc
Output voltage	+28 and -28 vdc
Regulation	1%
Power rating	+28v, 60 w
Power rating	-28v, 20 w
Minimum service	10,000 hr
Efficiency	60 percent min of rated load
Weight	6.5 lbs max
Size	7" x 6.23" x 3.25"
Connector	16-pin (Deutsch Co.)

This unit uses solid state electronics in its design; an oscillator of the multi-vibrator type is used with a transformer and rectifying circuit for the dc level transformation. For regulation, a phase shift regulator driven by a

magnetic amplifier is employed. Low output impedance is achieved by the use of a transistorized regulator employed as an output device. Short circuit protection and current limiting automatic fuses will provide this unit with the capability of working into any overload from rated to short circuit without resultant damage. Separate checkout connectors are provided to enable the monitoring of voltage and current.

This converter unit uses two multi-vibrator oscillators which employ junction transistors for the power switching elements and a saturable core reactor as the frequency-sensitive feedback element. The primary windings of the master and slave oscillators are interconnected in series so that each oscillator will supply half the power. Multiple windings on the output transformers of the two oscillators furnish the +28 volt and the -28 volt output. The combined outputs of the master and slave oscillators will be a quasi-square wave that is fed into parallel silicon diodes for full wave rectification and filtering. See Fig. 3-2 for converter power system.

Voltage reduction will be accomplished by using the phase angle of the master and slave oscillators. When the input voltage is low and the output loading is high, the two oscillators will be in phase. If the input voltage is high and the output loading is light, the phase relationship will approach 100 deg out of phase. As this condition occurs the quasi-square wave output will buck, and the output voltage will be reduced. A magnetic amplifier controls the phase angle of the two oscillators. Drive power for the magnetic amplifier is furnished by the master oscillator, and this will in turn control the slave

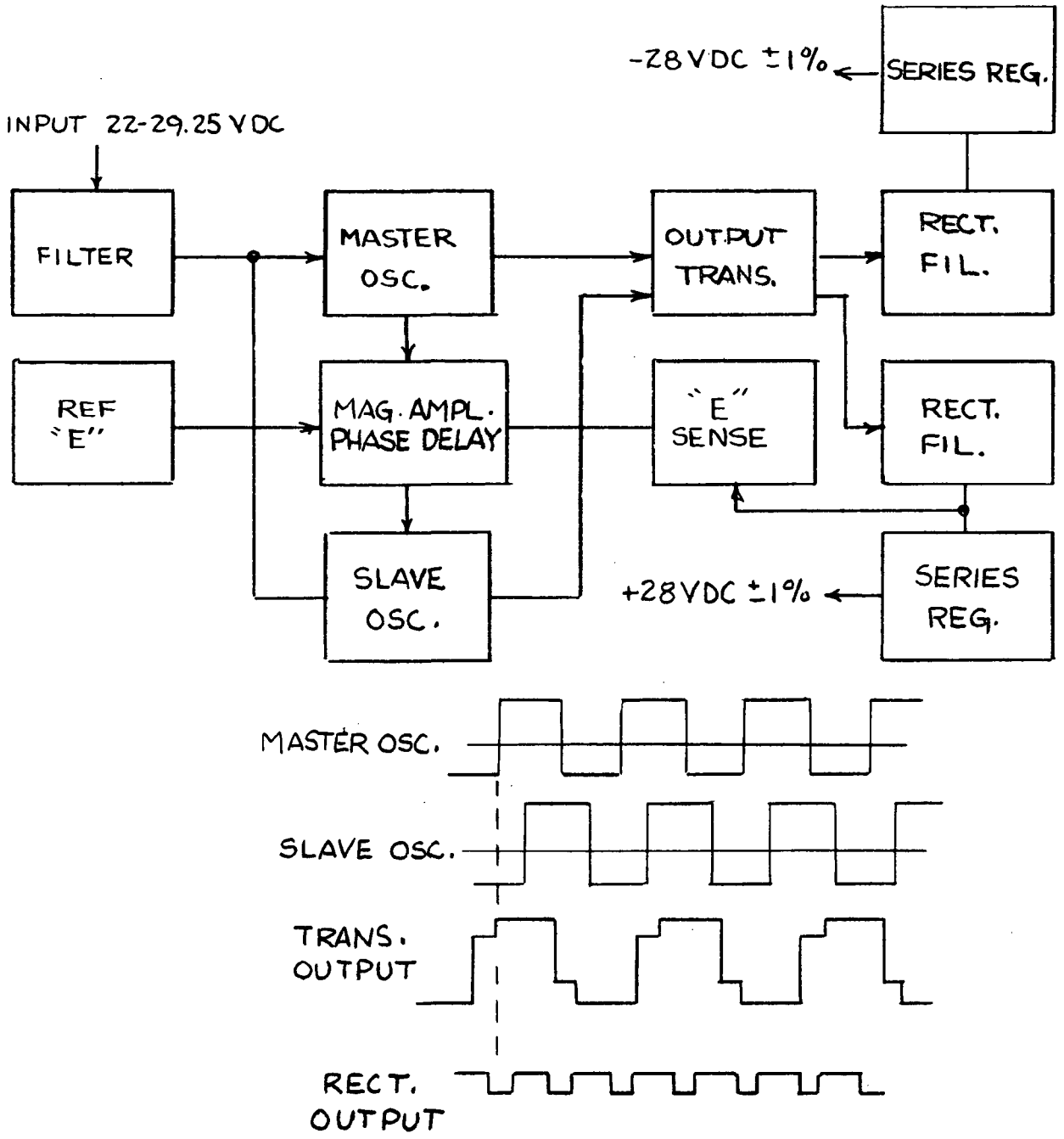

Fig. 3-2 Block Diagram of DC-DC Converter

oscillator through the silicon rectifier control switch. The angle-of-fire of the magnetic amplifier is controlled by its saturation time. The time required for saturation is dictated by the amplitude of the voltage in its control windings. A precision resistor divider network senses the converter output voltage, and this voltage plus a voltage derived from an ultra-stable silicon zener diode will be applied to the control winding of the magnetic amplifier. The amplitude of this voltage controls the saturation time of the magnetic amplifier, which in turn controls the firing angle as mentioned above.

The output of the magnetic amplifier will be fed into the silicon rectifier control switch, which controls the base drive of the transistor in the slave oscillator. To provide a low output impedance, a transistor series-type regulator is employed for each output in addition to the phase shift regulation.

3.1.1.2 5-Volt Converter

To provide the two watts of regulated power necessary for the potentiometer-type transducers used in the measurement system, a separate 5-volt converter will be used. The basic requirements for this converter are summarized below.

Input voltage	22 to 29.5 vdc
Output voltage	5 v
Power rating	2 w
Regulation	0.1 percent
Size	4 x 5 x 1.5 in
Weight	6 lb
Output impedance	0.1 ohm

This unit will be a modification of the basic 28V unit and will be qualified to meet the environment encountered in the equipment compartment of the nuclear stage.

3.1.2 DC-AC Inverters

A requirement exists for 115 vac, 400 cps, single-phase, electrical power to be used for instrumentation. To provide this form of energy, an inverter has been selected that will have basic parameters as follows:

Input voltage	22 to 29.25 vdc
Output voltage	115 vac
Regulation	±1 percent no load to 100 w
Power factor	0.8 lagging to 0.95 leading
Output frequency	400 cps ±0.02 percent
Size	8.20 x 7 x 4 in.
Weight	10.75 lb max
Service Life	10,000 hr min

The inverter is a static type employing solid state logic and silicon control rectifier power circuitry to provide a sinusoidal output with low harmonic distortion. It has no moving parts and no electronic tubes, instantaneous starting with all silicon solid state devices.

A block diagram of the inverter is shown in Fig. 3-3.

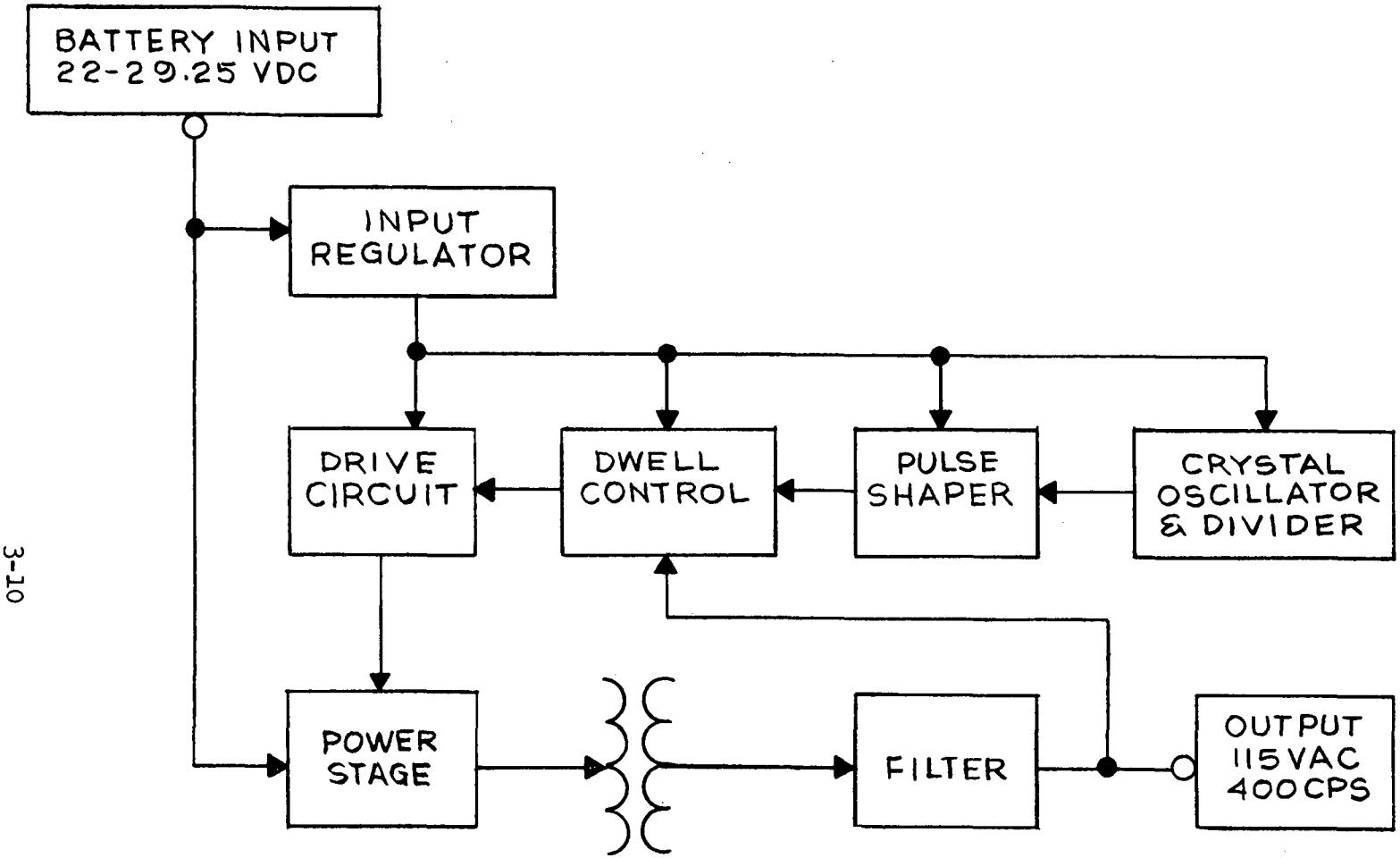

Fig. 3-3 Block Diagram, DC-AC Inverter

A low-level oscillator and divider system coupled to a control system is used to develop the drive signals for the transistor power stage. The signals are modulated by the dwell control to produce the proper drive signals. The output power stage utilizes silicon power transistors to produce a quasi-square wave voltage with a variable dwell time. Voltage regulation is obtained by varying the dwell angle θ

$$e_{out} = k E_{Batt} \text{ Cos } \theta \text{ sin } wt$$

The quasi-square wave voltage is then filtered by a resonant filter of several sections to produce a suitable sine wave voltage. Figure 3-4 illustrates the action of the dwell control.

3.1.3 Power Requirements

The S-N Stage power requirements based on the RIFT flight No. 2 with a single burn of the NERVA engine is pictured in Fig. 3-5. The voltage required is 28 vdc ±10 percent.

The instrument unit furnished by NASA containing the guidance package and the telemetry package for the S-I and S-II stages is separately powered from internal batteries.

A break-down of power consumption for the electrical and electronic equipment is listed in Table 3-2.

The engine power consumption is listed in Table 3-3 and shown in Fig. 3-6.

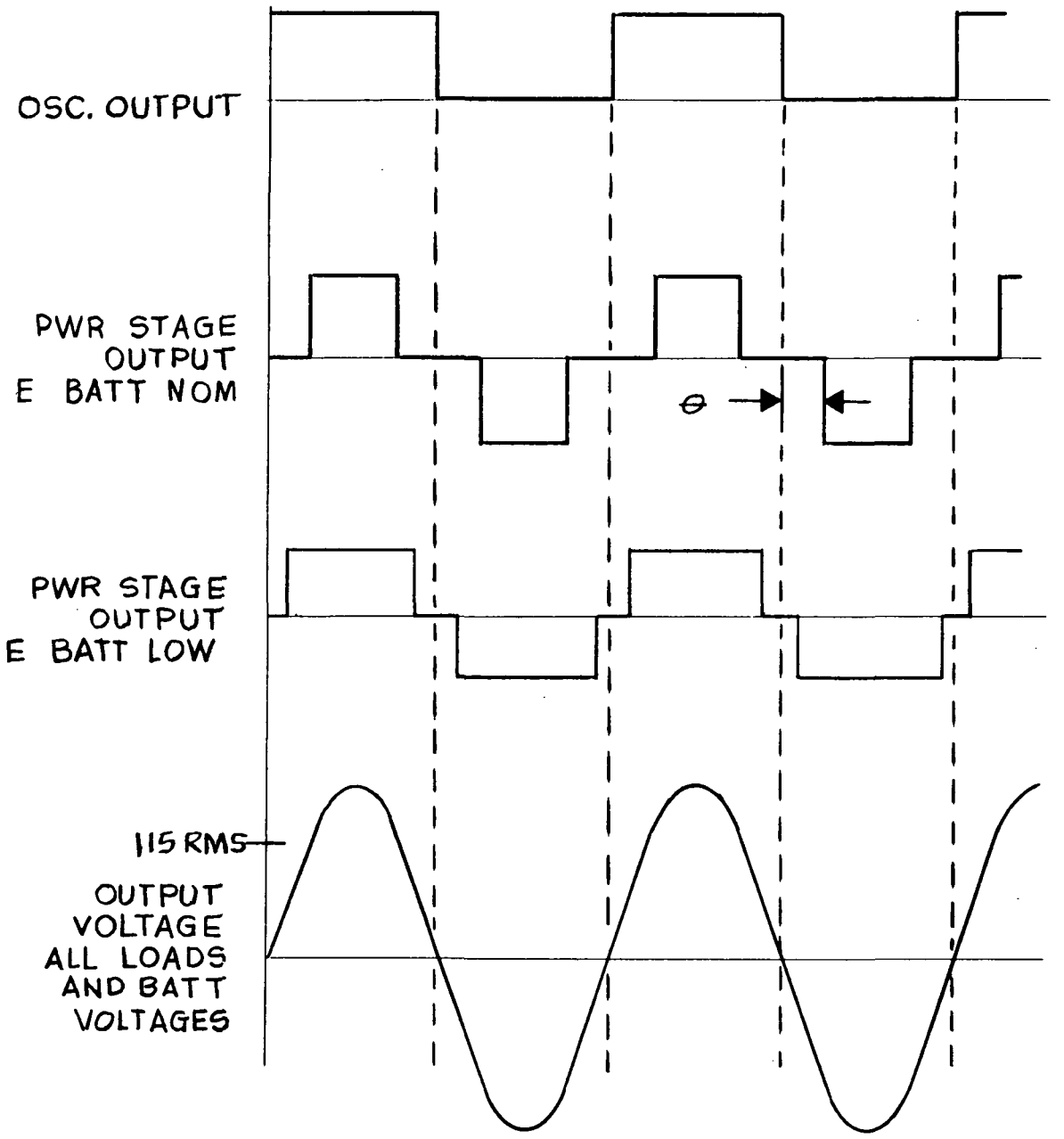

Fig. 3-4 Wave Shaper DC-AC Inverter

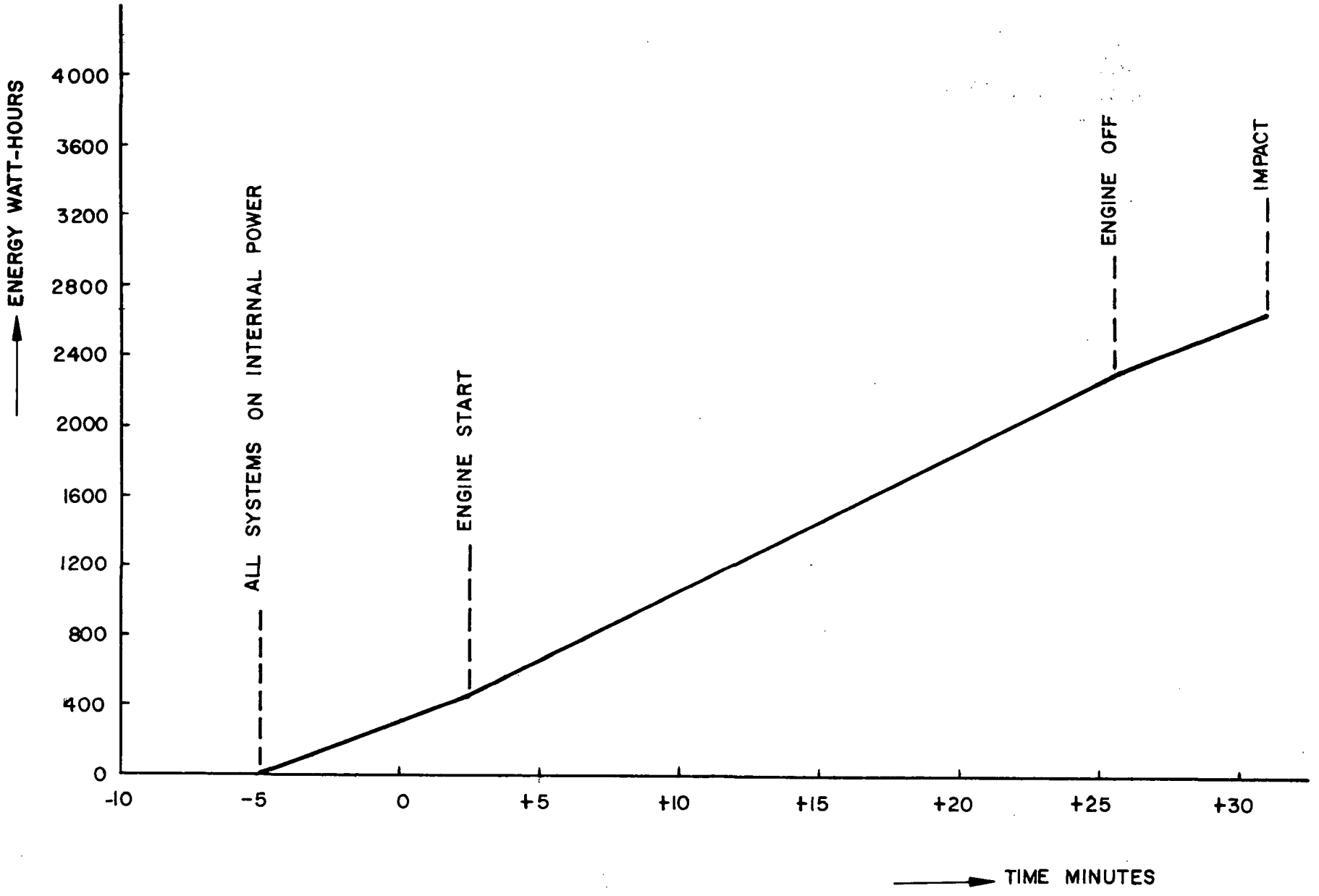

Fig. 3-5 Electrical Power Consumption RIFT Flight No. 2

Table 3-2

EQUIPMENT POWER CONSUMPTION

No.	Equipment Name	Power (W)	Energy (WH)
11	PAM-FM-FM Telemeters	2750	1720
1	SS-FM Telemeters	20	12
13	Power Amplifier	2180	1365
1	PCM Checkout Telemeter	165	103
1	LH_2 Level Ind.	32	21
14	Flow Converters	19	13
40	Radiation Detectors Electr.	160	110
1	Signal Cond. Ampl. Package	412	276
1	T.C. Signal Cond. Package	12	8
1	Beacon C-Band	150	92
1	Azusa	330	203
1	±28V Converter	55	37
1	+5 V Converter	3	2
1	115 V Inverter	130	88
	TOTAL	6418	4050

Total engine electrical energy requirements are defined in Table 3-3. Specific regulation requirements, such as voltage control or AC frequencies, have not been defined by the Engine Contractor. This power, including any required regulation, will be delivered to the engine from the S-N Stage primary power system.

Table 3-3

ENGINE POWER CONSUMPTION

Symbol	Function	Power (w)	Time (sec)	Energy (w-hr)
A	Launch	170	450	21.0
B	Start	2400	35	23.0
C	Engine Operation	2000	1356	753.0
D+E	Engine Coast	200	300	16.7
			TOTAL ENERGY (w-hr)	813.7

3.2 POWER DISTRIBUTION

3.2.1 Intersystem Wiring

The interconnections between the systems in the S-N Stage are illustrated in Fig. 3-7. The sub-systems involved are the following:

- Instrument Unit furnished by NASA
- Measuring Subsystem
- Data Telemetry Subsystem
- Electrical Power Subsystem
- Tracking Subsystem
- Destruct & Command Subsystem
- Flight Control Subsystem
- Checkout Subsystem
- Engine Control Subsystem

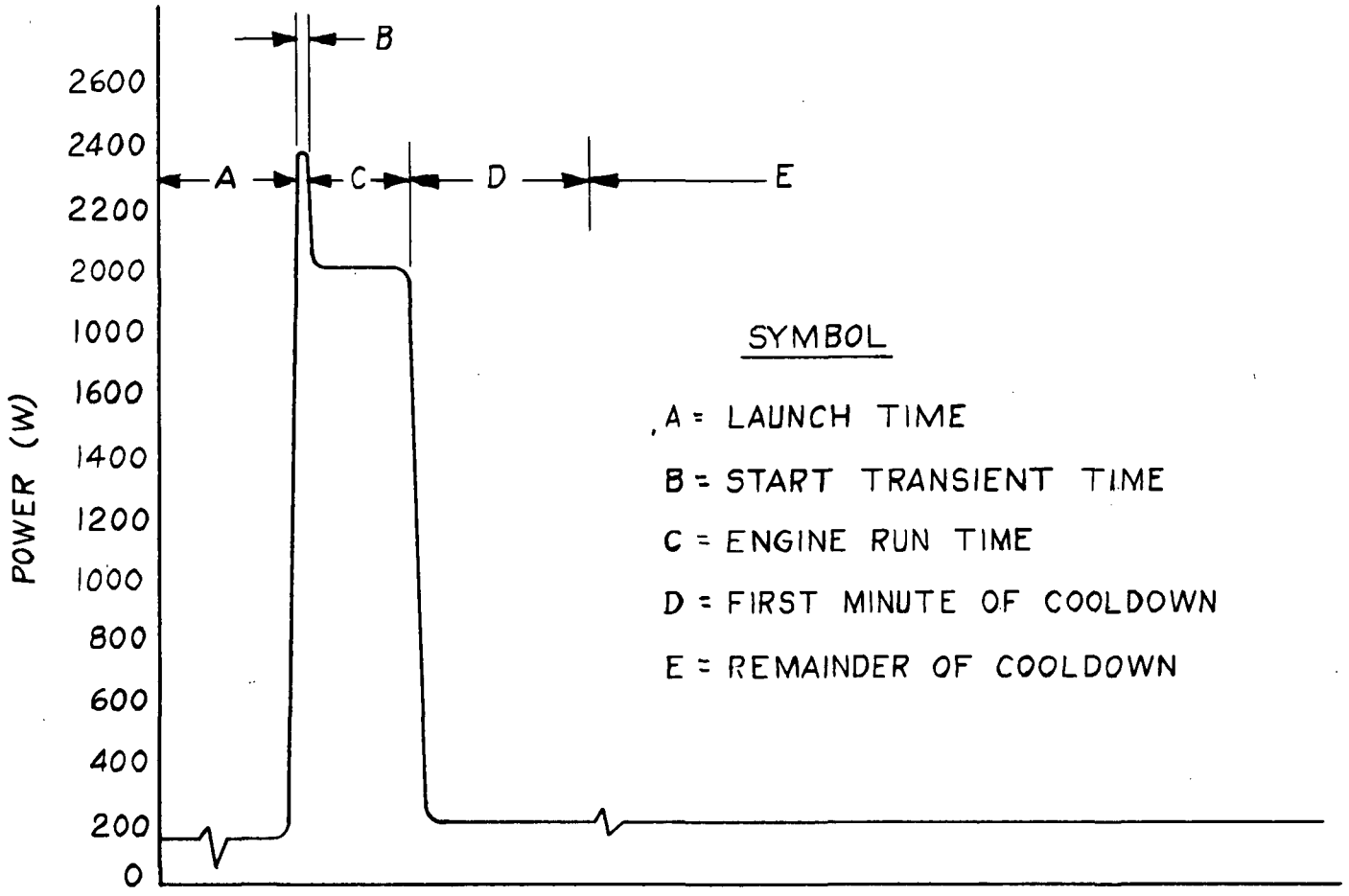

Fig. 3-6 Engine Power Time Consumption

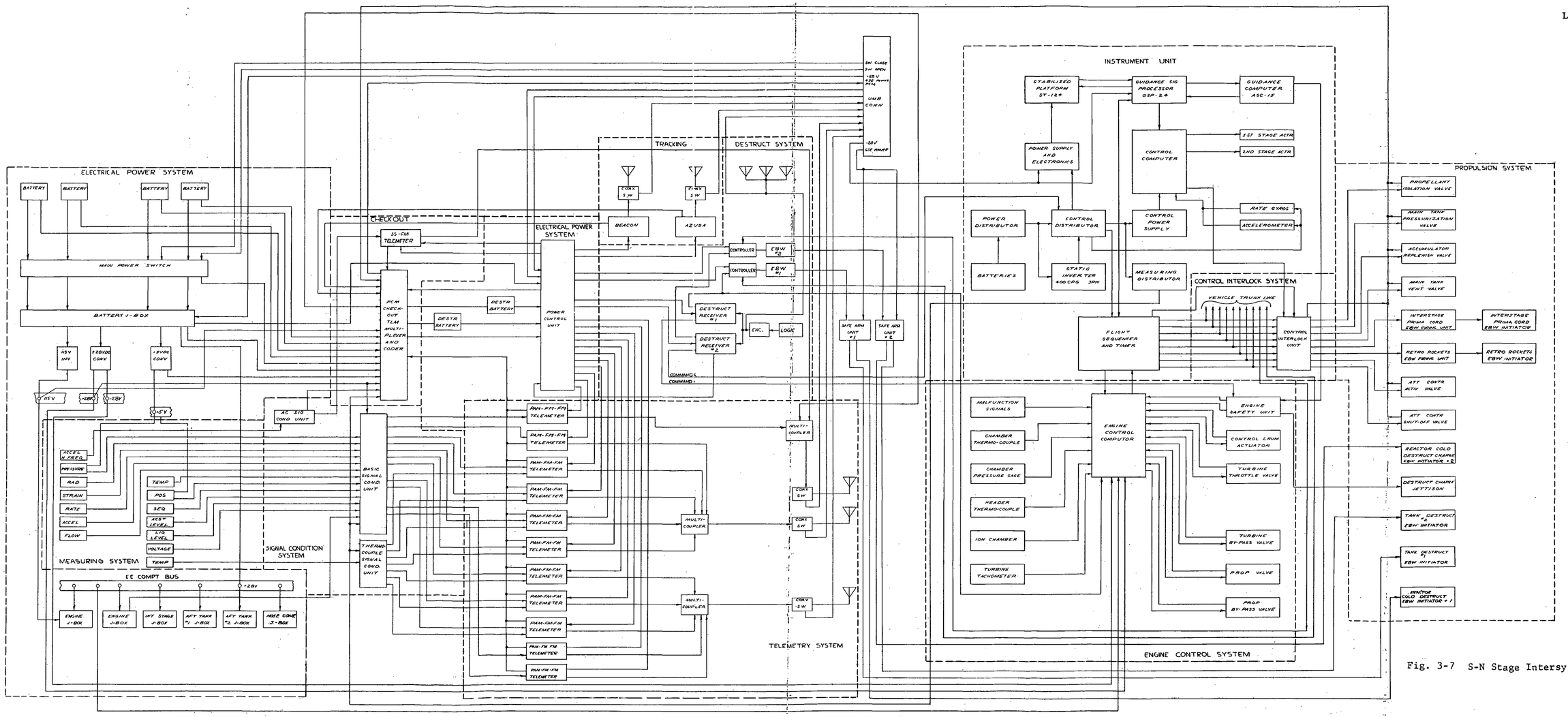

Fig. 3-7 S-N Stage Intersystem Wiring

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The interconnecting cables between the subsystems will be insulated with irradiated polyolefin and terminated into Deutsch DTK series connectors. These connectors are hermetically sealed. Connections in the plug are crimped and connections in the receptacles are soldered. The unshielded wire will be 19-strand tin-plated copper with irradiated polyolefin primary insulation.

The interconnecting cables will employ unshielded wire, twisted wire, and shielded wire, and will have an external irradiated polyolefin jacket.

The shielding will be grounded at one central point in the electronic compartment. The shield will be tin-plated copper, flattened and braided to cover at least 85 percent of the cable area. The cables will be designed to meet LMSC specification 01-4006A for high temperature and radiation environment.

The cabling required for the engine region equipment will be of ceramic type. Four-wire magnesium oxide-insulated cable with sheeting of stainless steel is presently available. The connector used on or near the engine will be the Physical Science Corporation PS type.

3.2.2 Interstage Wiring

3.2.2.1 Measurement Wiring

Several measurements on the booster stages will be made during the booster powered flight. The signal conditioning and transmitting equipment for these transducers will be located in the NASA-furnished instrument unit located in the

E-E compartment of the S-N Stage. The signal wires and cables will be routed through the S-N Stage and terminated in the instrument unit. Information concerning the instrument unit is incomplete, and any interface design in this area must be deferred until more information is available.

3.2.2.2 Control Wiring

The control wiring for attitude and engine control must pass through the S-N Stage in the same manner as the booster stage measurement wires. Again, the information available about the GFE equipment is inadequate for present design considerations.

3.2.2.3 Power Wiring

No interstage power wiring is presently planned. Each stage will carry its own power supply for internal use. Signal transfer between stages will be executed according to the general policy generated by MSFC and described in Sect. 3.3.2.

3.2.3 Distribution Boxes

3.2.3.1 Battery Junction Box

This junction box will receive power from the main power switch and distribute the power to the vehicle junction boxes, to the power conversion equipment, to the power switching equipment and to the main power bus in the electronic equipment compartment. See Fig. 3-8. The total current distributed by this junction box will be monitored and telemetered. See Fig. 3-9.

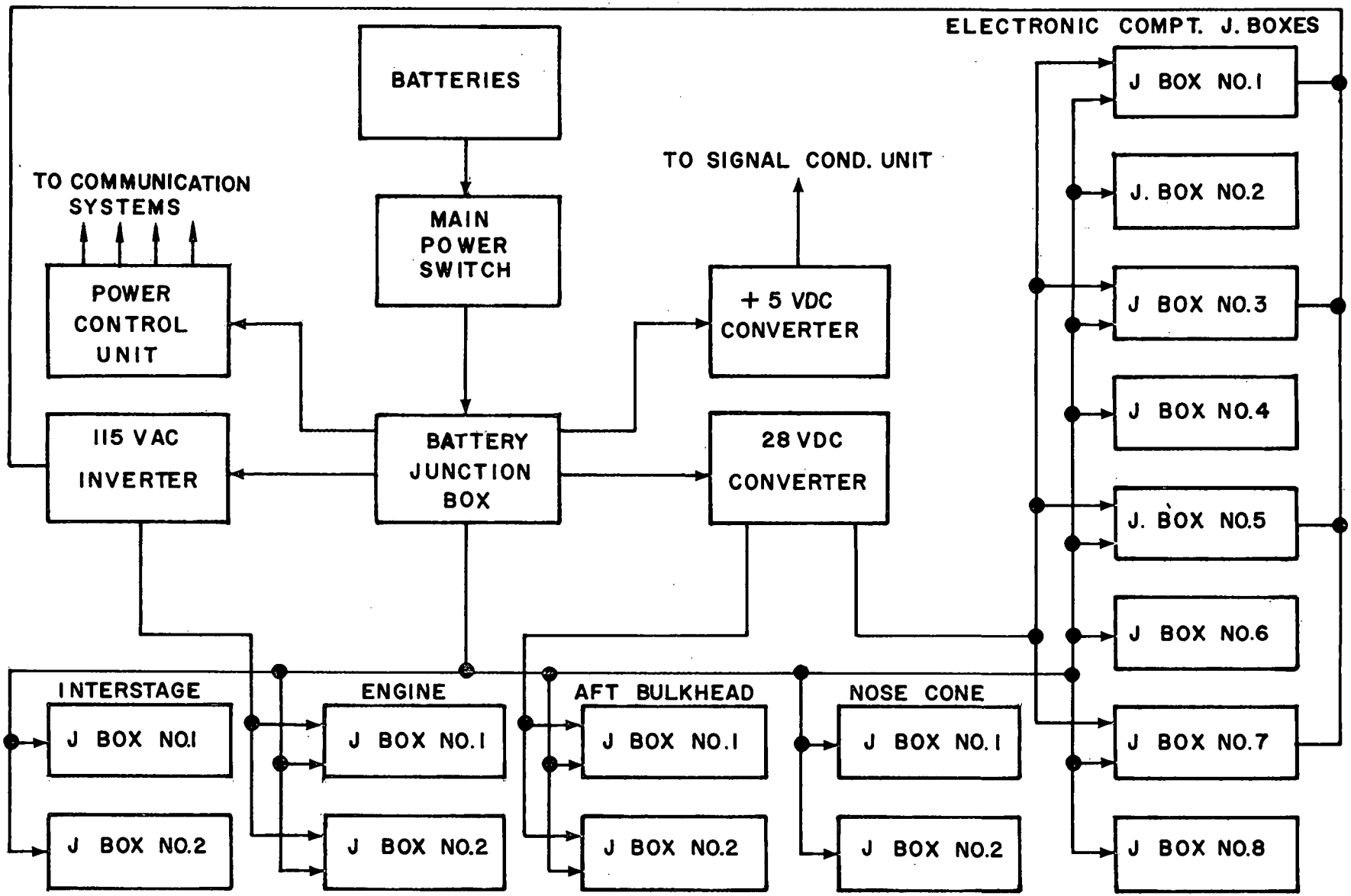

Fig. 3-8 Block Diagram, Power Distribution

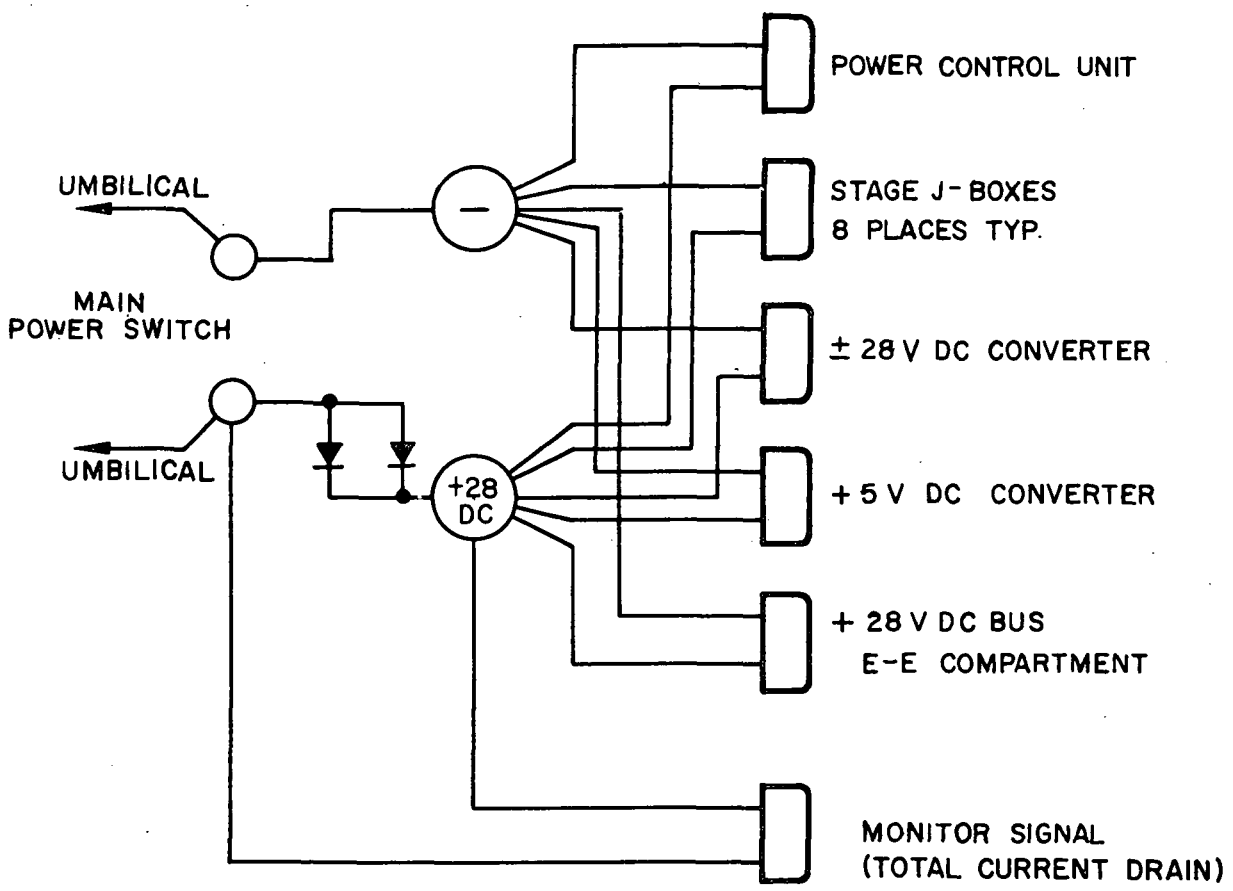

Fig. 3-9 Schematic Diagram, Battery Junction Box

The junction box will be hermetically sealed, and all connections will be made by Deutsch DTK type connectors. This type connector has been tested for moderate radiation environment and found satisfactory.

3.2.3.2 Vehicle Distribution Boxes

The junction boxes located in the S-N Stage as per Fig. 3-1 will be of a design similar to the battery junction box. Twenty power outlets providing 28 volts dc will be available in each junction box. The material of the boxes will be welded aluminum with removable lids. Connections will be made at the sides of the box.

3.2.4 Power Switching

The power for the nuclear stage will be switched at two levels; main power transfer switching and equipment switching. The main power transfer switching shown in Fig. 3-10 is motor driven by 28 vdc supplied through the umbilical connector. This switch is reversible and capable of being opened or closed on command. The switch has two poles rated at 60 amperes for power transfer and one pole rated at 5 amperes for the monitor signal.

Individual equipment switching will be accomplished through the power control unit by command signals from the checkout equipment and command decoder. The power control unit utilizes a number of self-latching miniature relays with contacts rated at 10 amperes. See Fig. 3-11. Closing or opening the relay is accomplished by applying a 28-vdc pulse of not less than 40 msec to the proper relay coil. Checkout is obtained by a monitoring signal. This equipment will perform satisfactorily when exposed to the environment within the equipment compartment.

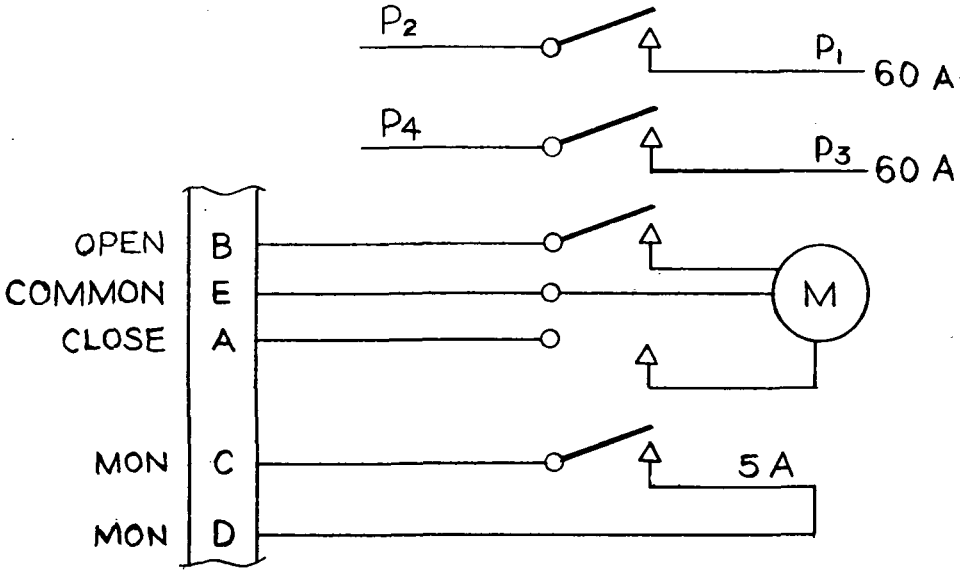

Fig. 3-10 Schematic Diagram, Main Power Switch

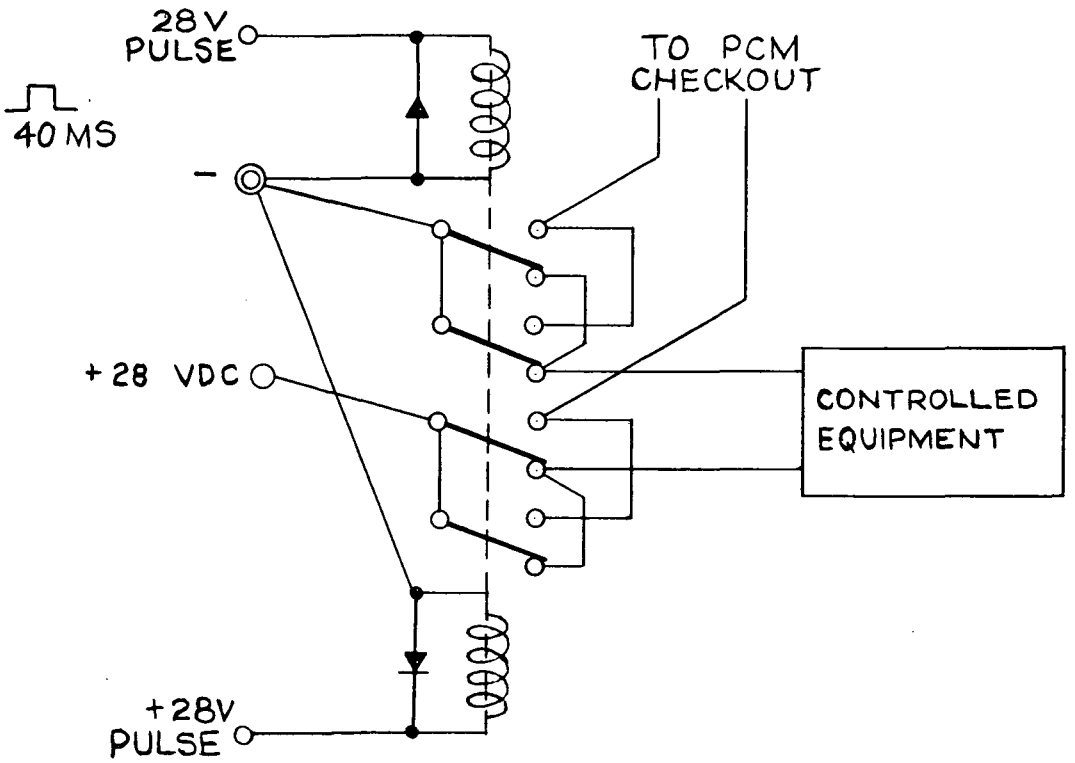

Fig. 3-11 Schematic Diagram, Power Control Module

The basic requirements for this main power switch are as follows:

- Rating: Two 60-a poles
- Monitor: One 5-a pole
- Actuation: Motor-driven, 22-29.25 vdc
- Connector: LS8739-1H-H-14-5PS
- Size: 3.5 by 3.89 by 2.90 in.
- Weight: 2.5 lb max
- Duty: Continuous duty

The power control unit for switching controlled equipment will be modular in design to provide for flexibility and to simplify troubleshooting. In the event of a failure of a component within the control unit, the malfunctioning module may be removed without voiding the entire test.

3.2.5 Connectors

3.2.5.1 Umbilical Connector

The umbilical connector will be of the "zero-entry" type featuring very low pull force and easy mating. This type of connector has been used with success in several missile programs. A series of modules employing zero-entry connectors is available and will be arranged in a package similar to the design illustrated in Fig. 3-12. The zero-entry design does not lend itself readily to coaxial connections. A separate coaxial umbilical connector is planned. Since the number of coaxial lines is small, a standard connector type Bendix PT07H-22-7 is proposed. This connector provides seven coaxial connections in a small standard shell disconnected by lanyard.

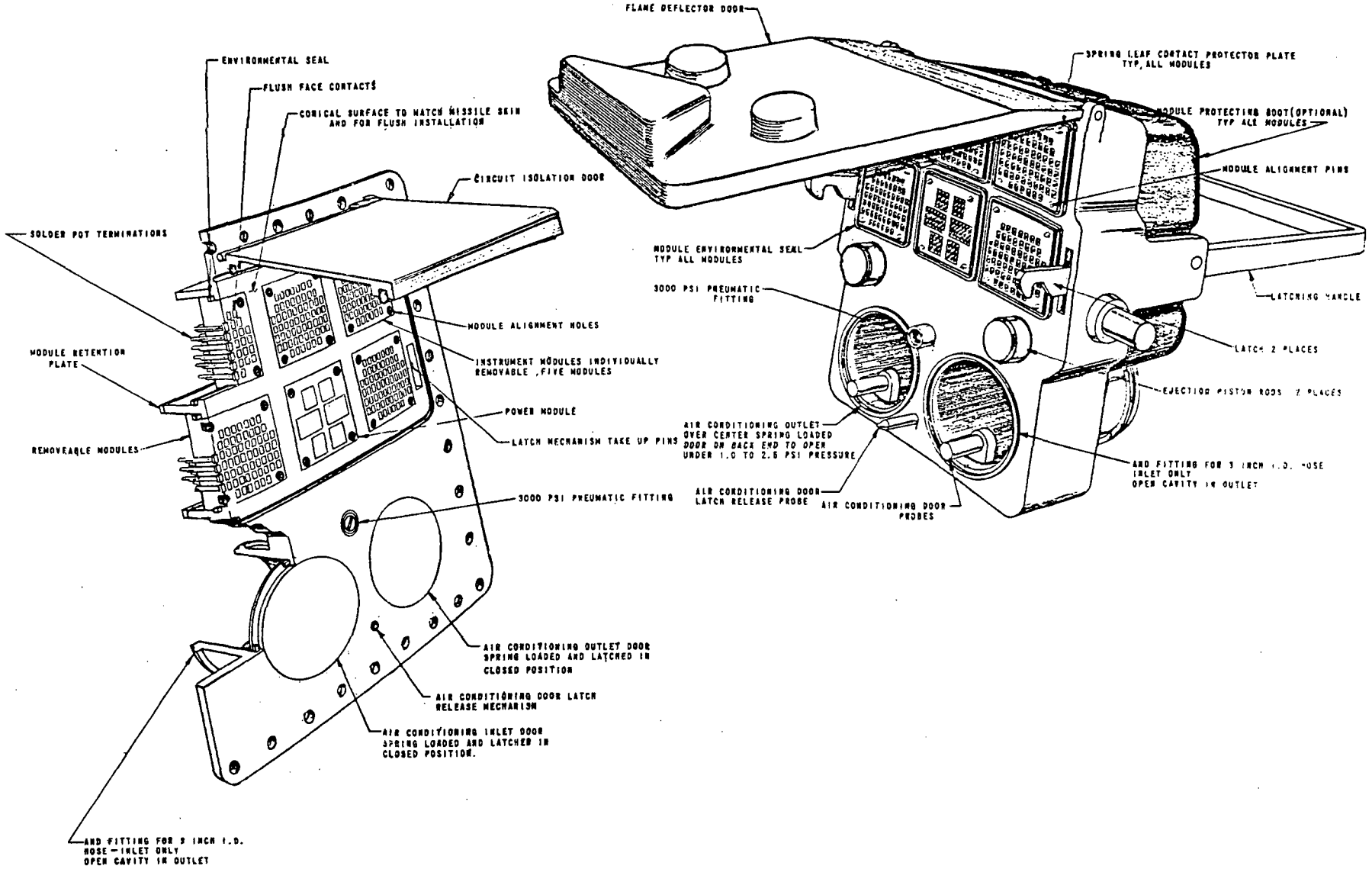
FLAME DEFLECTOR DOOR
ENVIRONMENTAL SEAL
FLUSH FACE CONTACTS
CONICAL SURFACE TO MATCH MISSILE SKIN AND FOR FLUSH INSTALLATION
CIRCUIT ISOLATION DOOR
SOLDER POT TERMINATIONS
MODULE RETENTION PLATE
REMOVEABLE MODULES
MODULE ALIGNMENT HOLES
INSTRUMENT MODULES INDIVIDUALLY REMOVABLE ,FIVE MODULES
POWER MODULE
LATCH MECHANISM TAKE UP PINS
3000 PSI PNEUMATIC FITTING
AIR CONDITIONING OUTLET DOOR SPRING LOADED AND LATCHED IN CLOSED POSITION
AIR CONDITIONING DOOR LATCH RELEASE MECHANISM
AIR CONDITIONING INLET DOOR SPRING LOADED AND LATCHED IN CLOSED POSITION.
AND FITTING FOR 3 INCH I.D. HOSE — INLET ONLY OPEN CAVITY IN OUTLET
SPRING LEAF CONTACT PROTECTOR PLATE TYP, ALL MODULES
MODULE PROTECTING BOOT(OPTIONAL) TYP ALL MODULES
MODULE ALIGNMENT PINS
MODULE ENVIRONMENTAL SEAL TYP ALL MODULES
3000 PSI PNEUMATIC FITTING
LATCHING HANDLE
LATCH 2 PLACES
EJECTION PISTON RODS 2 PLACES
AIR CONDITIONING OUTLET OVER CENTER SPRING LOADED DOOR ON BACK END TO OPEN UNDER 1.0 TO 2.5 PSI PRESSURE
AIR CONDITIONING DOOR LATCH RELEASE PROBE
AIR CONDITIONING DOOR PROBES
AND FITTING FOR 3 INCH I.D. HOSE INLET ONLY OPEN CAVITY IN OUTLET

Fig. 3-12 Umbilical Connector

3.2.5.2 Engine Region Connectors

All connectors required in the high radiation zone aft of the main propellant tank will be hermetically-sealed and radiation-resistant connectors. The power distribution boxes and the measurement junction boxes in this area will be equipped with the Physical Science Corporation connectors type PS. This connector provides a hermetic metal-to-metal seal and has been qualified for neutron doses up to 10^{20} nvt. This connector features a threaded disconnect secured by lockwire.

3.2.5.3 E-E Compartment Connectors

The radiation and temperature in the area forward of the main propellant tank is not as critical as in the engine region. A quick-disconnect connector of the pigmy type will be employed in this region. Sealing will be accomplished with a rubber seal between the mating parts of the connector. The Deutsch Co. Type DTK has been proven satisfactory for this application. This connector will be applied to all equipment and mating cables in the area forward of the main propellant tank.

3.2.6 Explosion Proofing

All electrical and electronic packages used in the S-N Stage and the umbilical tower will be tested according to MIL-E-5272 Procedure I. Conformance with MSFC Specification 10M01071 will be strictly enforced. Purging of all electrical equipment installation areas with GN_2 will be mandatory for all operations

involving H_2 within or in the vicinity of the S-N Stage of the RIFT vehicle. Hydrogen sensing instrumentation will be provided in electrical equipment areas for warning and monitoring purposes.

Particular emphasis will be paid to cable harnesses in the cryogenic environment to avoid cryogenic pumping and subsequent oxygen enrichment. Hermetically sealed connectors will be used throughout the stage. The umbilical connector will be purged by GN_2. Every effort to avoid high voltages in the equipment will be made by using transistorized circuitry and by eliminating switches and relays to the greatest extent possible.

3.3 FLIGHT SEQUENCE CONTROL SYSTEM

3.3.1 Logic

The purpose of the flight sequence control system logic is to control the sequence of events required for flight operation. A typical logic diagram is shown in Figs. 3-13a and 3-13b. Two criteria were used in deriving this logic diagram. First, adequate safety measures were provided, and second, the need for hardware changes for the four RIFT flights was eliminated. In addition, an assumption was made regarding the guidance computer's capacity to accept the programmed delay times shown in the logic diagram.

Particular provision is made for safety regarding the NERVA engine. An example of this is the logic to force lower-stage engine shutdown if a normal shutdown does not occur prior to predepletion signal plus 35 seconds. This

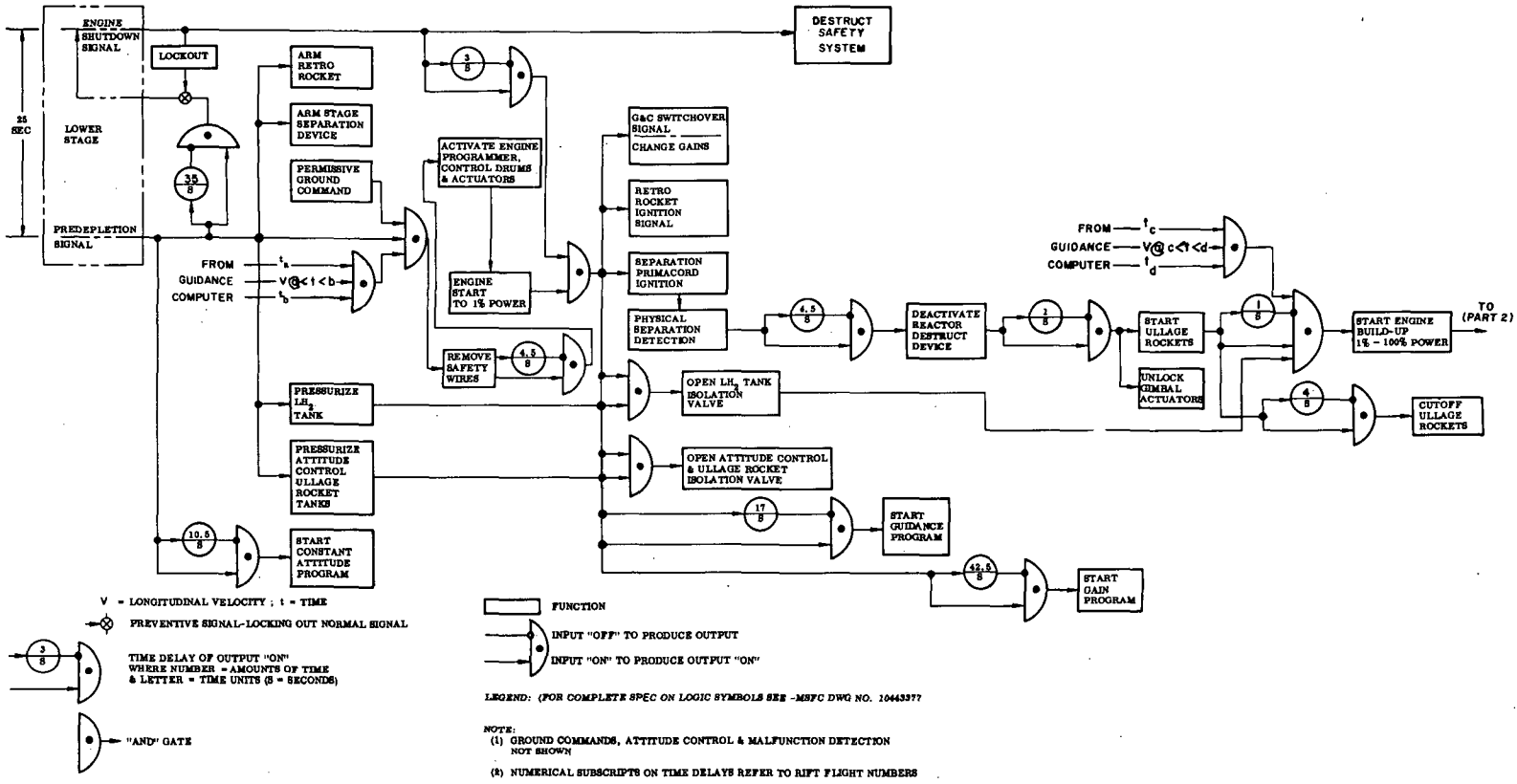

Fig. 3-13a Logic Diagram, Flight Sequence Control System

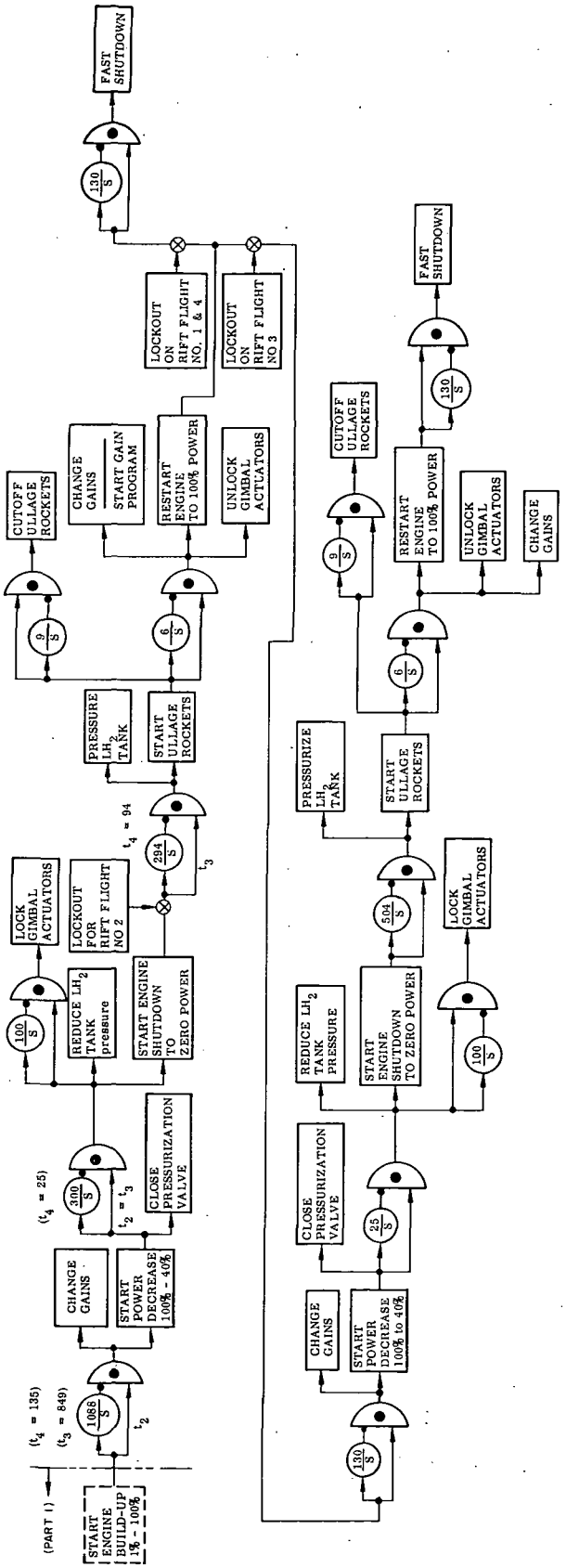

Fig. 3-13b Logic Diagram, Flight Sequence Control System

prevents the NERVA engine from operating at one percent power for more than 10 seconds. Another example is the use of a predetermined minimum longitudinal velocity to control the startup of the NERVA engine. This will insure that adequate velocity has been imparted to the vehicle by the S-IC stage. The logic has been arranged so that unwanted portions may be eliminated as indicated by flight sequences associated with the four RIFT flights.

The flight sequence logic will be in the flight sequence unit located in the equipment compartment. The guidance computer and the engine computer are located in the instrument unit.

3.3.2 Interface Signal Control

Input signals will be furnished by the lower stages through the trunk line to the logic circuitry. Where practical the instrument unit will provide the stimulation source for in-flight, time-based events. A circuit diagram to illustrate the control of signals across interfaces is shown in Fig. 3-14. Signals that are required by the nuclear stage prior to separation of the S-IC will come through the S-IC nuclear instrument unit interface. This philosophy is used to make certain that all signals required by adjacent stages are routed through the lower stage and so that no signal race can occur.

The method to be utilized in transmitting signals between stages shall be as follows: If Stage II requires a signal from Stage I, the 28 v will be furnished to Stage I by Stage II and Stage I will, in turn, switch the 28 v and return the switch signal to Stage II.

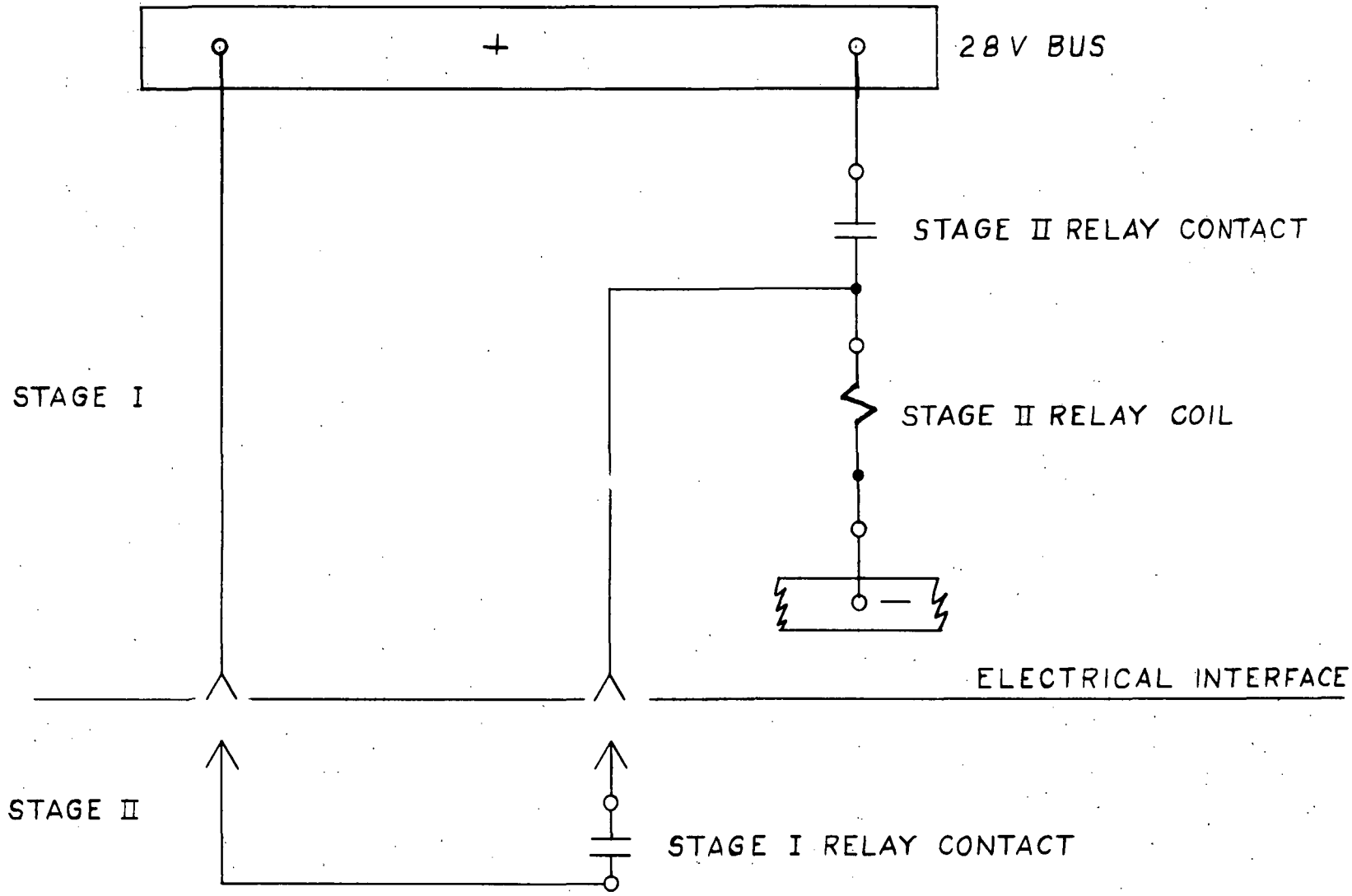

Fig. 3-14 Circuit Diagram – Interface Signal Control

The 28 v for signal transmission need only be furnished one time for a set of signals between stages. This method of signal transmission will allow the dc power of each stage to be completely independent and eliminates the problems of transferring current on the negative side of the dc power systems.

3.3.3 Checkout

The flight sequence control system will be checked out by monitoring the status of the indicators associated with the various valves, actuators and other flight control devices in the S-N vehicle. The checkout equipment will provide a "go" or "no-go" signal for each flight sequence event. These status signals will be sent to the PCM checkout telemetry system.

3.4 FLIGHT CONTROL INTERLOCK SYSTEM

3.4.1 General Description

The flight control interlock system will be a part of the flight sequence unit located in the S-N Stage. A trunk line or cable will be carried through all stages of the vehicle. Each stage will contain a switching device which will tie its control system to the trunk line. See Fig. 3-15. Control of the switching device in each stage will be provided by circuitry in the instrument unit. This circuitry provides an electrical interlock system which makes it impossible to connect electrically more than one stage to the trunk at any one time. The switching device shall be the source indicated by and controlled by DAC drawing 7866039. This switch is a 96PDT unit with connections made by seven Bendix type PT07E connectors. Each switch contact detents into an operated position to provide positive latching action.

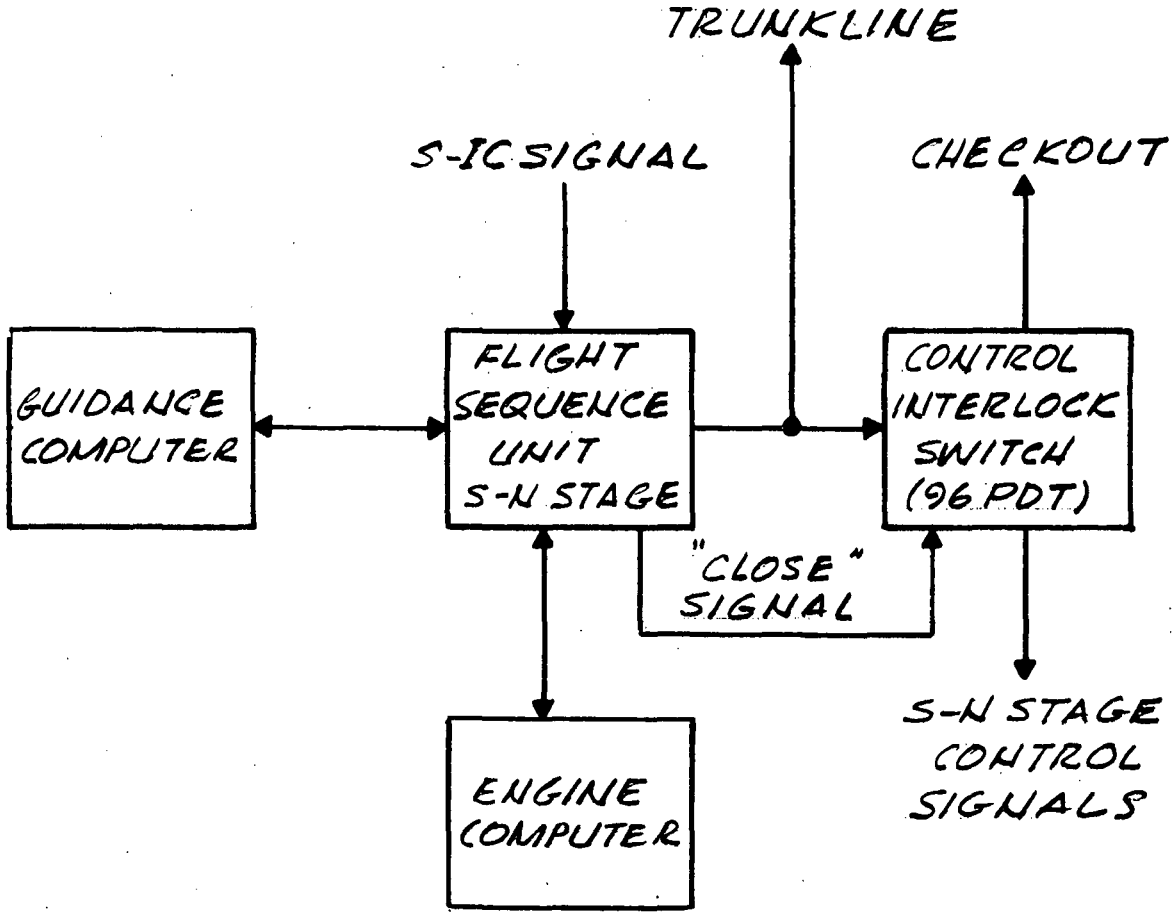

Fig. 3-15 Block Diagram, Flight Control Interlock System

3.4.2 Logic

The logic for the flight control interlock system is shown in Fig. 3-16. Specific events must have taken place and proper conditions must exist for the vehicle before the transfer of flight control. Indications of these events and conditions will be given by the guidance computer, the engine computer, and the instrument unit. Data from these sources will be received by logic circuitry in the flight sequence unit. This will result in the operation of the flight control interlock switch which will permit the flight sequence unit to proceed with S-N Stage flight operations.

An AND gate in the flight sequence unit receives S-IC engine data, a time signal from the guidance signal processor and S-IC separation data. The output of this AND gate signals a relay driver to operate a latching power relay. Actuation of the power relay will cause power to be applied to the motor of the interlock switch. The interlock switch requires 28 vdc at 10 a for operation.

3.4.3 Checkout

The checkout of the flight control interlock system will be accomplished by monitoring the status of the interlock switch. A positive 5 v signal will be sent to the PCM checkout telemetry and to the checkout equipment through a set of normally-open switch contacts.

3.4.4 Signal Flow

The flow of signals for flight control is determined by the status of the flight control interlock switch. When flight control is related to lower stages, the

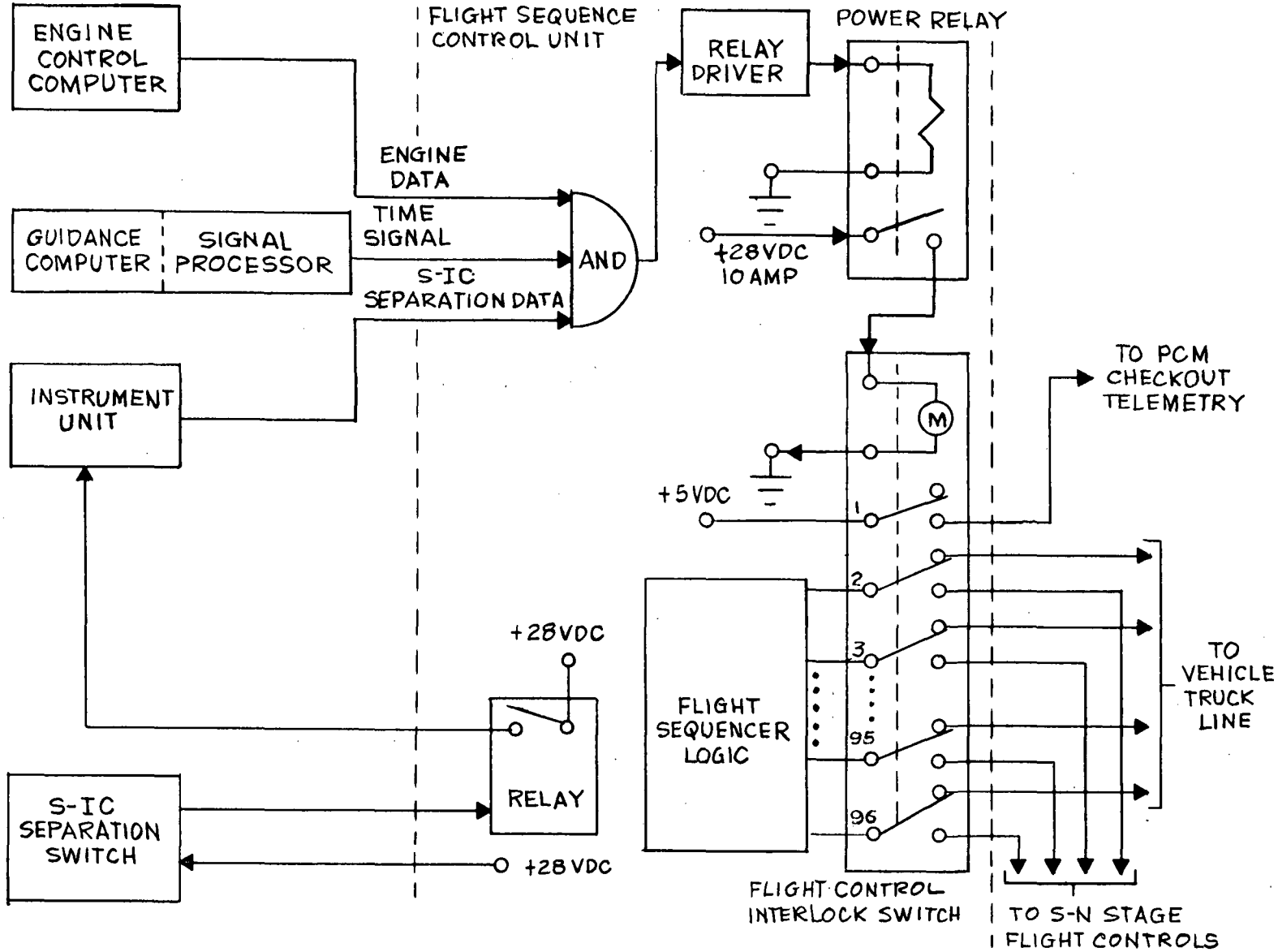

Fig. 3-16 Logic Diagram, Flight Control Interlock System

flight control interlock switch is in the de-energized condition. Flight sequence control signals then flow to the vehicle trunk line through normally closed interlock switch contacts. When the guidance and control system, in conjunction with the engine computer, sends appropriate signals to the flight sequence interlock logic, the interlock switch will energize and transfer flight control signals through normally open switch contacts. The flight control signals will then be directed to various functions under control of the flight sequence control system.

3.5 DESTRUCT SAFETY SYSTEM

3.5.1 Logic

The purpose of the destruct safety system is to evaluate the integrity of the vehicle with particular emphasis on the condition of the S-N stage. The safety system will be designed for an unmanned development vehicle. However, the design criteria for automation and response time of the elements within the RIFT destruct safety system shall be consistent with and as stringent as those required for the S-IC and S-II stages being developed for manned flights.

A logic diagram for the destruct safety system is shown in Fig. 3-17. This logic will receive signals from various sensors which are monitoring particular parameters associated with the RIFT engine, guidance and control, the stage structure, and the propellant system. The safety logic includes decision circuits which will allow some parameter values to be tolerated without causing auto-destruct,

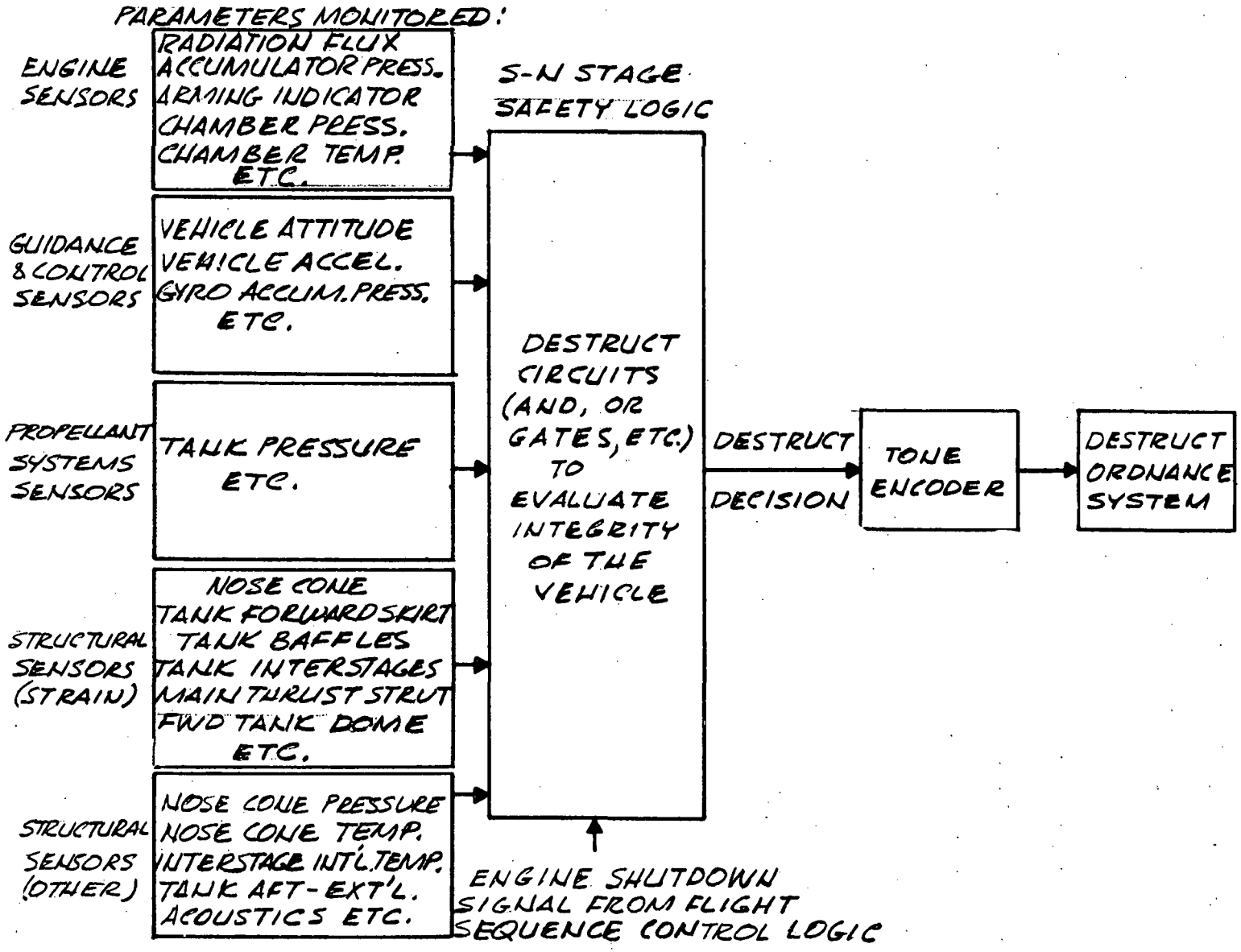

Fig. 3-17 Logic Diagram, Destruct Safety System

but which will bring about auto-destruct when these values are coincident with certain other parameter conditions. These circuits will provide for immediate auto-destruction upon recognition of intolerable conditions, particularly those associated with the nuclear engine.

The destruct signal generated by the decision circuits will pass to a tone encoder which will change the signal to a tone form compatible with the command destruct receivers.

Since the safety system must meet all the requirements of range safety, consideration will be given to the inclusion of redundant logic.

3.5.2 Location of Monitor Points

Emergency detection system monitor points will be established within the propellant system, the guidance and control system and the nuclear engine system.

3.5.2.1 Propellant System

The following parameters are monitored through the umbilical data link when available or through tracking and real-time telemetry: hydrogen leaks, tank pressure, accumulator pressures, purge pressures, vent gas composition, propellant overfill sensor, arming indicator, and propellant valve positions.

3.5.2.2 Guidance and Control System

The following parameters are monitored through tracking and real-time telemetry: trajectory, vehicle attitude, vehicle acceleration, gyro accumulator pressure, ullage chamber pressure, attitude chamber pressure, and actuator pressure.

3.5.2.3 Nuclear Engine System

The following parameters are monitored through the umbilical data link and real-time telemetry: radiation flux, control drum position, inert purge pressure, accumulator pressure, safety lock indicator, arming indicator, pump outlet pressure, chamber pressure, chamber temperature, and core safety wire removal.

3.5.3 Destruct System Description

The nuclear stage destruct system will integrate tank destruct and reactor destruct subsystems and be activated by either a self-generated signal or on command. An exploding bridgewire command destruct system has been established for this vehicle and fulfills the requirements of regulation AFMTC 80-7. A block diagram of the system is shown in Fig. 3-18.

The destruct system for the main propellant tank consists of two linear shaped charge which extend from the intersection of the tank bottom within the tank wall, upward along the outside of the propellant tank and over a portion of the tank top. Each linear charge will use its own separate EBW initiator.

The reactor destruct system furnished by the engine contractor will be coordinated with the propellant tank destruct system into a completely integrated S-N Stage destruct system consisting of:

- An omnidirectional antenna system feeding both command receivers
- Two command receivers (G F E) each operating from a separate destruct battery

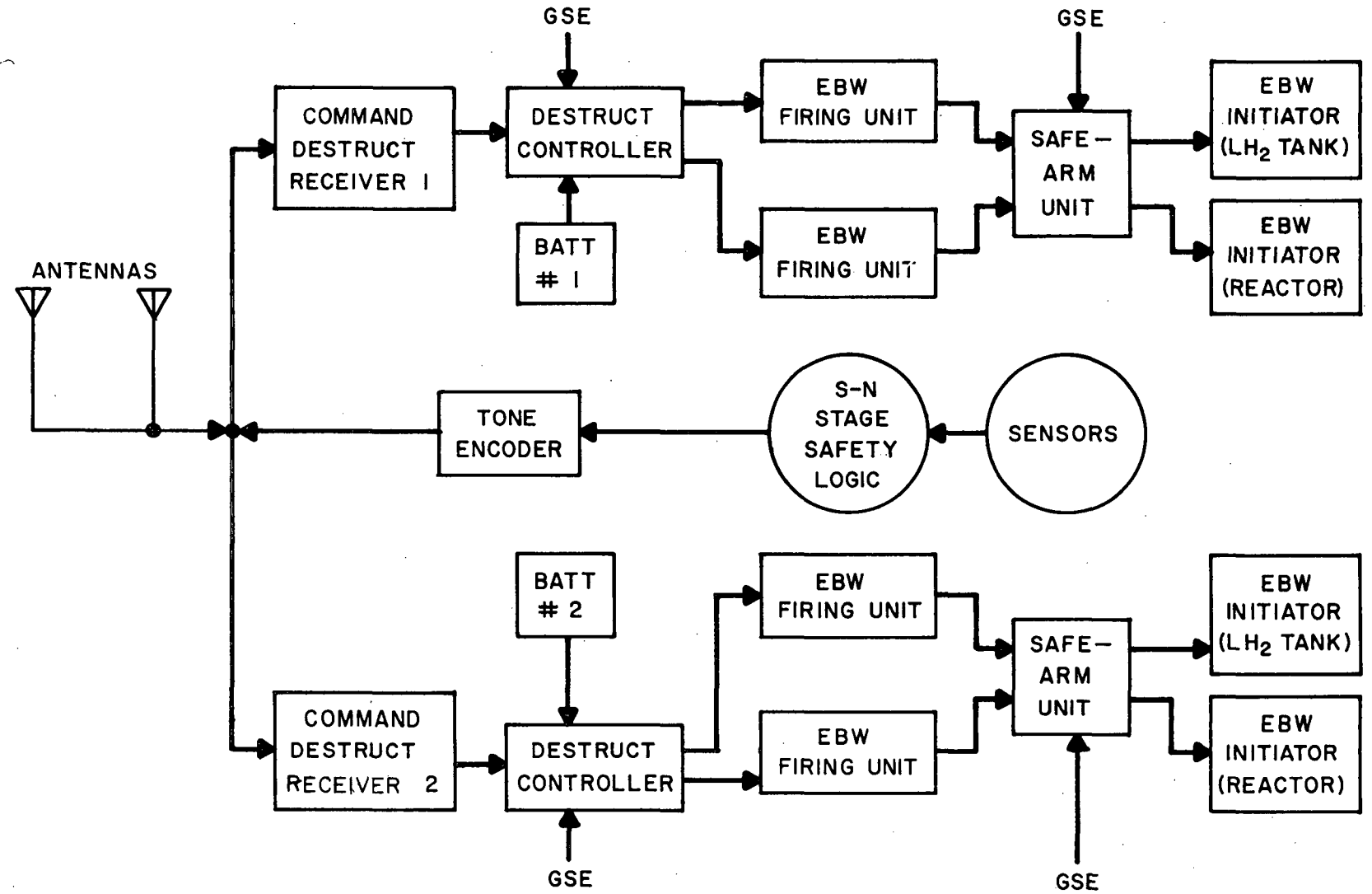

Fig. 3-18 Block Diagram, Command Destruct Safety System

- Four EBW firing units, two for each receiver operating from the same battery as the associated receiver (To be procured by drawing number from a source designated by MSFC)
- Two destruct system controllers (G F E)
- Four EBW initiators, one for each firing unit
- An ordnance system capable of being initiated from either EBW initiator for stage destruction. This system receiver contains two GSE-controlled safe-arming units. An ordnance interface between adjacent stages will be provided to assure the destruction of the entire vehicle in all conditions. (Same interface as that used in S-I and S-II stages)
- A timer provided for insertion of a time delay between the arming command execution and the destruct command execution. This delay is intended for manned flights only.
- A command destruct receiver. The destruct receiver is described in Section 2.6 of this report.

3.5.3.1 EBW Destruct System Controller

This unit controls the command destruct receiver, the EBW firing unit, and the necessary signals to the vehicle system for thrust termination. This unit is universally applicable to all stages of the vehicle and is capable of being adapted to manned or unmanned, orbital or non-orbital flights. Selection of the various modes of operation is accomplished by insertion of a replaceable module into one of the controller connectors. Interconnections are accomplished by the use of four connectors mounted on the unit.

The wiring of this unit will be according to a wiring diagram furnished by MSFC, with modifications to accommodate two command destruct receivers and four EBW firing units.

3.5.3.2 EBW Firing Unit

The explosive bridgewire firing unit is a power storage unit employing a bank of capacitors charged to a high voltage. An external trigger signal will discharge the capacitors into the bridgewire thereby initiating the destruct charge. A block diagram of the EBW firing unit is shown in Fig. 3-19. The design of this unit will be similar to the unit described in Douglas Aircraft Co. Inc. specification 7865719. The major performance data is listed below.

Weight:	3.6 lb
Size:	6 by 3.5 by 3 in.
Input voltage:	24 to 36 vdc
Input current:	1.5 a max for 4 sec
Storage voltage:	2300 ±100 vdc
Storage time:	4 sec max
Bleed time:	15 sec to 300 v
Trigger voltage:	28 ±4 v
Response time:	4 ±1 msec
Trigger current:	110 ma min, 200 ma max

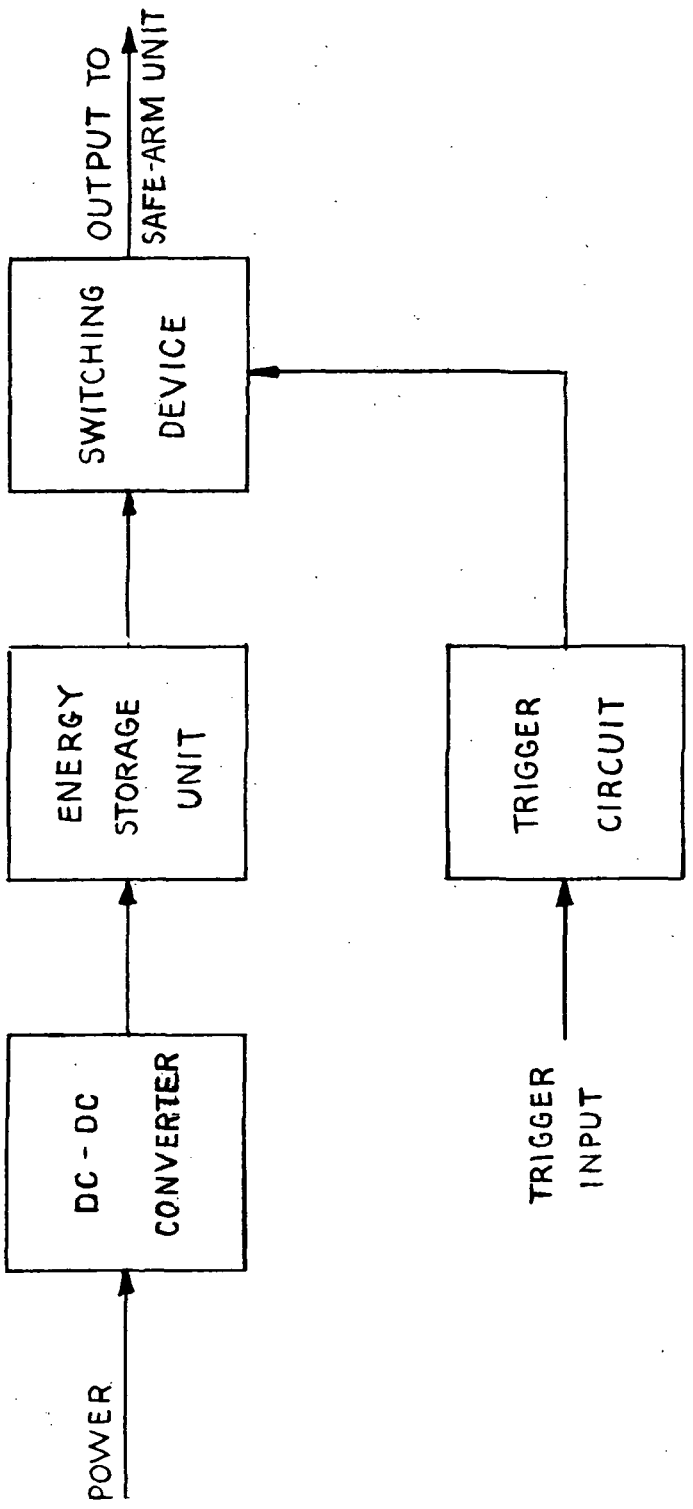

Fig. 3-19 Block Diagram, EBW Firing Unit

3.5.4 Checkout

3.5.4.1 S-N Stage Safety Logic Checkout

The sensors associated with the safety logic will be checked out in a manner similar to that described in Sections 1.4 and 1.5. The conditions of the sensors will be monitored by checkout equipment using a calibration unit in conjunction with a signal conditioner. This equipment will simulate the sensor inputs to the safety logic. Monitor points will be provided in the decision circuits to indicate the status of the circuits while operating from simulated inputs. A means of monitoring the decision output will be included. A portion of the checkout equipment will be designed to monitor the output tones from the tone encoder. The GSE-operated controllers associated with the command destruct receivers will inhibit the destruct signal from the tone encoder during checkout.

3.5.4.2 Destruct Ordnance System Checkout

The checkout for the destruct ordnance system will be accomplished by utilizing equipment presently available for checkout of other Saturn stages. The destruct system controller is an example of this equipment, since it includes features for checkout and monitoring. Monitoring equipment will be provided to assure safety of the destruct system. EBW pulse checkers and test sets will be procured by drawing numbers from a source designated by MSFC.

3.6 STAGE SUBSTITUTES

Proper utilization of stage substitutes will help ensure satisfactory operation of an integrated vehicle. Equipment simulating a RIFT stage will provide control and checkout electrical inputs to adjacent stages. The equipment will be modular in design, thereby providing ease of maintenance and added flexibility.

Electrical signals will be provided to adjacent stages to simulate the operation of the RIFT stage during checkout and flight. In the absence of a stage in the checkout of a vehicle, realistic simulated operation will ensure compatibility of the S-N Stage with the S-IC and the instrument unit when mated.

Since very little input is exchanged between the S-N and S-IC directly, and the bulk of the electrical interface is with the instrument unit, the design of this stage substitute will require complete coordination with MSFC.

The substitutes will include the simulation of: position feedback to control circuits, control circuits to actuators, attitude control and indication, emergency detection systems, cut-off control and indication, destruct system, flight control, etc. In general, the circuits are to include active and passive networks as required. See Fig. 3-20.

3.7 ENVIRONMENTAL HARDENING

The general design problem encountered in internal system design is the verification of the integrating equipment. Since only a small number of the equipments considered for the RIFT program have a previous flight history, it will be

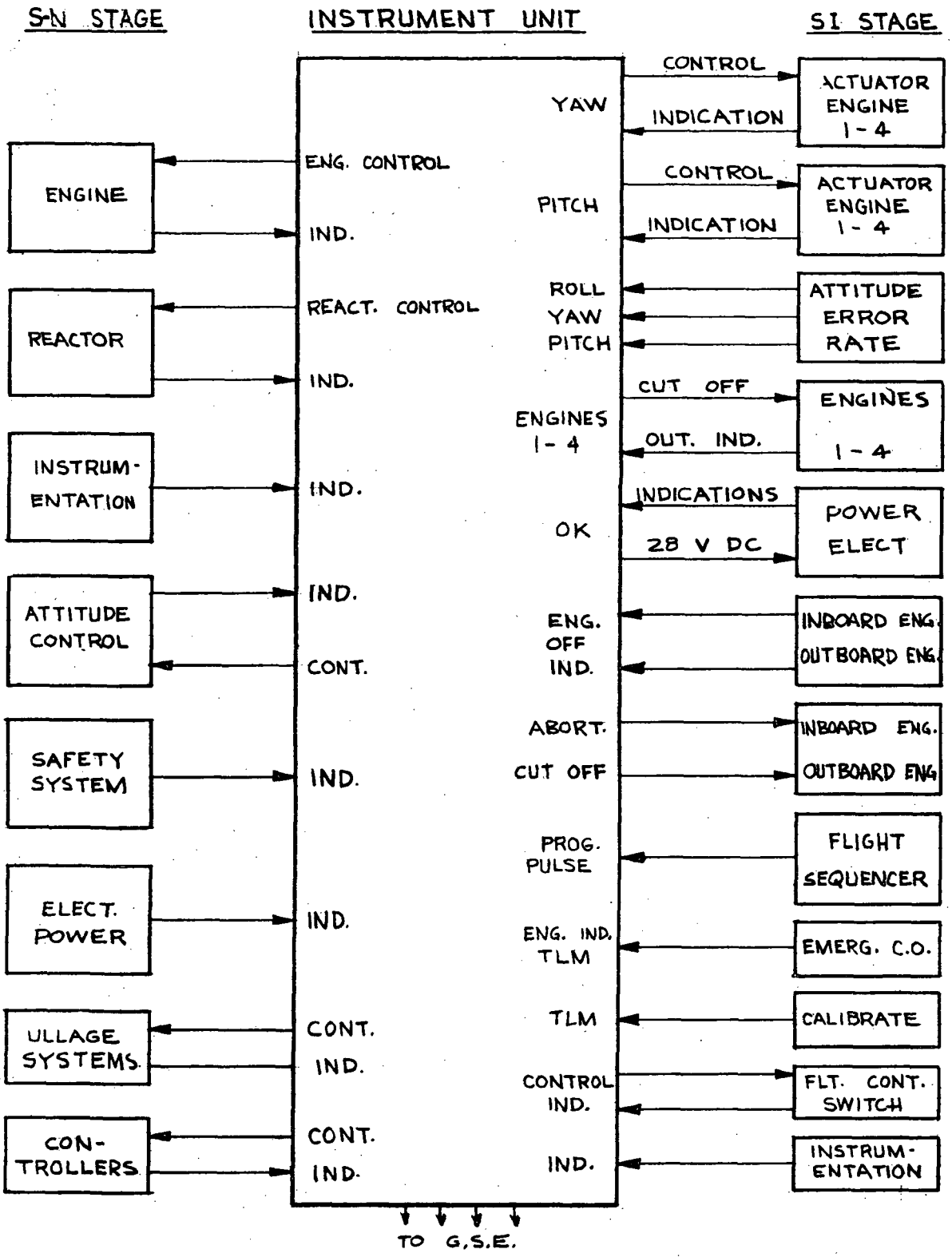

Fig. 3-20 Block Diagram, Stage Substitutes

mandatory that all new designs be subjected to a development test phase which will eventually terminate in a formal qualification of the equipment for the RIFT application.

The new and unproven designs will be subjected to continuous design review culminating in a complete design review report. Circuit analysis will be an important part of this review. Other factors which will be analyzed in the review are mechanical design, handling ability, reliability design and environmental performance. The present documented and approved flight equipment will be reviewed, with emphasis on reliability and past service history. Improvements based on pertinent failure reports will be suggested to the manufacturer.

Since a complete theoretical analysis of the equipment performance and reliability under expected environment is time-consuming and complex, a test program to verify the basic performance calculated in the performance analysis will be carried out. These tests will be adjusted to the particular equipment need and the expected environment. Tables 3-4, 3-5 and 3-6 are typical summaries of the indivudual tests. A test procedure for each particular type of equipment will be created and used as a guide in conducting the tests.

The proposed test activity will be divided into three parts: functional test, environmental tests, and post-environmental test. The functional test will establish the ability of the test unit to perform according to specification in a laboratory environment and will also serve as a reference for the tests mentioned below. The environmental test will employ the simulated environment

Table 3-4

TELEMETRY SYSTEM TEST PROGRAM

EQUIPMENT NAME: Electronic Commutator

TEST SUMMARY: Perform an environmental test of the equipment while monitoring critical parameters representative of the equipment flight performance.

DESCRIPTION OF SAMPLE: The commutator is an electronic switch capable of sampling a multitude of applied voltages in the range of 0-5 volts. The commutator will sample the applied voltages sequentially and deliver a composite pulse train output with individual pulses representing the applied voltages.

NO. OF SAMPLES: Three required.

ENVIRONMENTAL REQUIREMENTS: (See Tables 3-7 and 3-9)

- Sinusoidal vibration
- Random vibration
- Temperature
- Shock
- Moisture
- Explosive atmosphere
- Pressure

PARAMETERS TO MONITOR:	RANGE:
Linearity and maximum output	0-7 v
Zero input noise	0-100 mv
Pulse duration and frequency	0-25 μsec at 40 kc
Input and output impedance	5000 ohm - 2 megohm
Signal limiting	5.5 v
Crosstalk and common mode rejection	-60 db

INSTRUMENTATION REQUIRED:	ACCURACY:
Power supply, 28 vdc, 3 a	1%
Oscilloscope and camera	5%
Signal simulator	±1%
Counter	±1 count
Digital voltmeter	0.1%
Ammeter	3%

Table 3-5

ELECTRICAL SYSTEM TEST PROGRAM

EQUIPMENT NAME: Electrical Umbilical Connector

TEST SUMMARY: Perform a complete evaluation program to evaluate the performance and quality under simulated RIFT vehicle conditions.

DESCRIPTION OF SAMPLE: The electrical umbilical connector will provide a junction between the GSE and the S-N Stage for transit of electrical power and signals for checkout purposes. The same connector will also provide transit of compressed nitrogen for purging purposes.

NO. OF SAMPLES: Three required.

ENVIRONMENTAL REQUIREMENTS: (See Tables 3-7 and 3-9)

- Sinusoidal vibration
- Random vibration
- Temperature
- Shock
- Moisture
- Explosive atmosphere
- Pressure

PARAMETERS TO MONITOR:	RANGE:
Pull force	0-100 lb
Insulation resistance	10-1000 megohms
RF channel isolation	-70 db
Current heating	-65° to +200°F
Voltage drop	0-2 v

INSTRUMENTATION REQUIRED:	ACCURACY:
Force gauge	3%
Insulation tester	5%
Signal generator	5%
Noise analyzer	5%
Oscilloscope	3%
Ammeter, 200 a	3%
Digital voltmeter	1%

Table 3-6

MEASURING SYSTEM TEST PROGRAM

EQUIPMENT NAME: LH_2 Level Indicator

TEST SUMMARY: Perform functional and environmental test to evaluate the test samples performance under simulated S-N Stage conditions.

DESCRIPTION OF SAMPLE: The LH_2 Level Indicator consists of a variable capacitance probe, an ac bridge completion network, a null-balancing potentiometer servo and a power supply. The liquid level change will cause a change of the capacitor dielectric constant and unbalance the ac bridge. The servo will rebalance the bridge and provide readout.

NO. OF SAMPLES: Three (Pending successful radiation test.)

ENVIRONMENTAL REQUIREMENTS: (See Tables 3-7 and 3-9)

- Sinusoidal vibration
- Random vibration
- Temperature
- Moisture
- Shock
- Voltage variations
- Pressure
- RFI induced, Ref. MIL-26600

PARAMETERS TO MONITOR:	RANGE:
Full scale output	0-5 v
Linearity	0-5 v
Frequency response	0-10 cps
Repeatability	0-5 v
Sensitivity	0-100 mv

INSTRUMENTATION REQUIRED:	ACCURACY:
Power supply 28 vdc, 3 a	5%
Oscilloscope	5%
Digital voltmeter	0.1%
Mechanical liquid level indicator	0.1%

expected in the flight article. Important parameters will be monitored during these tests. The post-environmental test will establish the degree of degradation due to the environment encountered. The tentative environmental requirements are listed in Table 3-7. The equipment required to produce these environments is listed in Table 3-8.

A sequence of environments or combination of environments will be employed in the testing. The sequence is outlined in Table 3-9. The combination of environments, outlined in Table 3-9, of input voltage combined with a mechanical environment, such as vibration, temperature, etc., is recommended from the practical standpoint and will give important information for a moderate expenditure on equipment.

The test data will be analyzed and tabulated so that a direct comparison between the performance analysis and the reduced test data is possible. Where test data from several test samples is available from a sequential type test, the test sequence shall be specified. The analysis of the test data shall be based on proper calibration data for all measuring devices, a profound knowledge of the test article and the test equipment, and a pertinent error analysis of the measuring equipment.

If an inferior performance of the equipment is indicated by analysis of the test data, the design organization shall be contacted and the design review shall be extended to the area of the inadequacy.

Table 3-7

ENVIRONMENTAL TEST PROGRAM

Vibration:

Sinusoidal Vibration	5 to 20 cps	1/4" da	3 axes
	20 to 400 cps	5 g vector	
	400 to 800 cps	7.5 g vector	
	800 to 3000 cps	15 g vector	

Random Vibration:	0.10 g^2/cps, 3 axes, 20-2000 cps bandwidth
Linear Acceleration:	20 g, 3 axes for 5 min
Shock:	20 g on 3 axes for 11 msec
Temperature:	-65° to +200°F (alternate -65° to + 400°F)
Input Voltage:	(where applicable) +31.5 and +25 v
Pressure:	10^{-3} mm Hg

Nuclear Radiation:

Neutron Flux (fast)	10^{14} neutrons/cm^2 sec	Engine Region
Neutron Dose (fast)	10^{17} neutrons/cm^2	
Gamma Flux	10^{9} r/hr	
Gamma Dose	10^{8} r	
Neutron Flux (fast)	10^{8} neutrons/cm^2 sec	Equipment Compartment
Neutron Dose (fast)	10^{9} neutrons/cm^2	
Gamma Flux	10^{5} r/hr	
Gamma Dose	10^{4} r	

Moisture:	100% relative
Explosive Atmosphere:	According to MIL-E-5272 Procedure I modified to the RIFT program

Radio Frequency Interference: According to MIL-I-26600

Table 3-8

ENVIRONMENTAL TEST FACILITIES

Vibration:	Electro-dynamic shaker 5000 force-pound Amplifier and equalization equipment Sinusoidal and random noise generators Accelerometers and amplifiers for monitoring Oscilloscope for display Stroboscope for visual inspection
Linear Acceleration:	Centrifuge with control panel Oscillograph for recording
Temperature:	Temperature chamber for -70°F to +500°F Temperature monitoring equipment Oscillograph for recording Cryogenic test bench
Altitude:	Altitude chamber capable of 10^{-3} mm Hg Vacuum pump and pressure monitoring equipment Leak detector Oscillograph for recording
Nuclear Radiation:	Radiation sources neutron and gamma Radiation detectors neutron and gamma Shielded test facility
Shock:	Shock machine Impact tester Oscillograph Oscilloscope and camera
Explosive Atmosphere:	Explosion proof facility Explosion test set
RF Interference:	Screen room RFI test set

Table 3-9

SEQUENTIAL TEST PROGRAM

Test	Input Voltage								
	High	Low	High	Low	High	Low	High	Low	High
Sinusoidal Vibration	A1					C6		B8	
Shock		A2					C7		B9
Temperature	B1		A3					C8	
Random Vibration		B2		A4					C9
Pressure	C1		B3		A5				
Moisture		C2		B4		A6			
Explosive Atmosphere			C3		B5		A7		
Radiation				C4		B6		A8	
Acceleration					C5		B7		A9

A1 = First sample, first test

A2 = First sample, second test

B1 = Second sample, first test

B2 = Second sample, second test

C1 = Third sample, first test

C2 = Third sample, second test

3.8 ELECTRICAL INTERFACES

The electrical interfaces within the S-N Stages are as follows:

Interface	Transfer Device
S-N Stage - S-II Stage	Vehicle trunkline connector, lanyard pull-spring operated. Pin side of connector on the S-II stage. AN/MS 3106 connector inserts, or use of the Wiggins style zero-entry connector
S-N Stage - Nuclear Engine	Flange-mounted integral connector, mating by external feeler pins. Pin side of connector on the engine mating flange. AN/MS 3106 connector inserts, or Wiggins style zero-entry connector.
S-N Stage - Nose Cone Cap	Instrumentation connector, integral flange connector type, mated by feeler pins. Pin side in the nose cone cap. AN/MS 3106 connector insert or Wiggins style zero-entry connector.
S-N Stage - Nose Cone	Instrumentation connector, lanyard pull-spring operated. Pin side of connector on the nose cone side. AN/MS 3106 connector inserts or Wiggins style zero-entry connector.

Interface	Transfer Device
S-N Stage - Instrument Unit	Vehicle trunkline connector, lanyard pull-spring operated, pin side of connector on the instrument unit side. PT06 type connector.
S-N Stage - GSE	Umbilical connector, lanyard pull-spring operated, pins on GSE side. Inserts Wiggins style zero-entry connector.

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